Stormwater Management Study of the Redhill Creek Watershed City of Hamilton

Phase B: Watershed Modelling

Philips
Planning
+ Engineering
Limited

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April 27, 1983.
Our File 80046

Mr. Konrad Brenner, P. Eng.,
Regional Municipality of Hamilton-Wentworth,
Engineering Department,
City Hall, 71 Main Street West,
Hamilton, Ontario.
L8N 3T4

Dear Sir:

RE: Stormwater Management Study of Red Hill Creek Watershed

We are pleased to submit our findings on the Red Hill Creek Stormwater Management Study.

The study has been presented in the following two reports:

- Phase A: Stormwater Management Techniques
- Phase B: Watershed Modelling

This Phase B report details the hydrologic modelling methodology, layout and study results. Numerous data tables and tabled results are included as well as the following information under separate cover as requested:

- cross-section plots (sections used in HEC-2 hydraulic modelling)
- rating curve plots
- hydrology (SUBHYD-ROUTE) printouts for modelling
- HEC-2 (hydraulic) printouts

Should you have any questions or wish any further information, please do not hesitate to contact us.

Yours very truly,

PHILIPS PLANNING + ENGINEERING LIMITED

Karen Dennison

Karen D. Dennison, P. Eng.,
Project Manager.

KDD/bls
Encl.

STORMWATER MANAGEMENT STUDY

OF THE

RED HILL CREEK WATERSHED

CITY OF HAMILTON

PHASE B: WATERSHED MODELLING

APRIL, 1983

PHILIPS PLANNING + ENGINEERING LIMITED
Consulting Engineers and Town Planners
Burlington, Ontario
L7R 3Y2

(Project: 80046)

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- Reach 711 - 10 Year Storm Future Conditions
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- Reach 711 - 25 Year Storm Future Conditions
- Reach 711 - 100 Year Storm Existing Conditions
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- Reach 712 - 5 Year Storm Future Conditions
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- Reach 715 - 10 Year Storm Future Conditions
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- Reach 715 - 100 Year Storm Future Conditions

LIST OF ILLUSTRATIONS, FIGURES AND MAPS

ACKNOWLEDGEMENTS

The assistance and input of the following people in the carrying out of this study and production of this report is gratefully acknowledged:

- Mr. Konrad Brenner, P. Eng. of the Hamilton-Wentworth Engineering Department, who coordinated the study for the City of Hamilton and provided information on drainage divisions, future landuse patterns and the practicality of various stormwater management techniques from an administrative point of view. Mr. Brenner served on the Technical Coordinating Committee.

- Mr. Doug Christilaw, P. Eng. of the Hamilton-Wentworth Engineering Department who assisted in the compilation of storm sewer data for the watershed and served on the Technical Coordinating Committee.

- Mr. Werner Plessl, P. Eng. of the Hamilton Region Conservation Authority who served on the Technical Coordinating Committee and provided valuable input on watershed management goals from the point of view of the Conservation Authority.

- Mr. Larry Thompson, M.A.Sc., P. Eng. who, although no longer with our firm by the conclusion of the study, carried out much of the work and provided generous amounts of his own time to explain the work carried out. Appreciation is also expressed to Mr. Thompson for making his SUBHYD-ROUTE hydrologic modelling sytem available for use on this project.

1.0 INTRODUCTION

1.1 Background and Purpose of the Report

This stormwater management study Phase B report on watershed modelling of the Red Hill Creek has been prepared for the City of Hamilton by Philips Planning and Engineering Limited.

This report discusses and presents the watershed hydrologic considerations and analyses undertaken in the course of this study. Specifically, the following items are included:

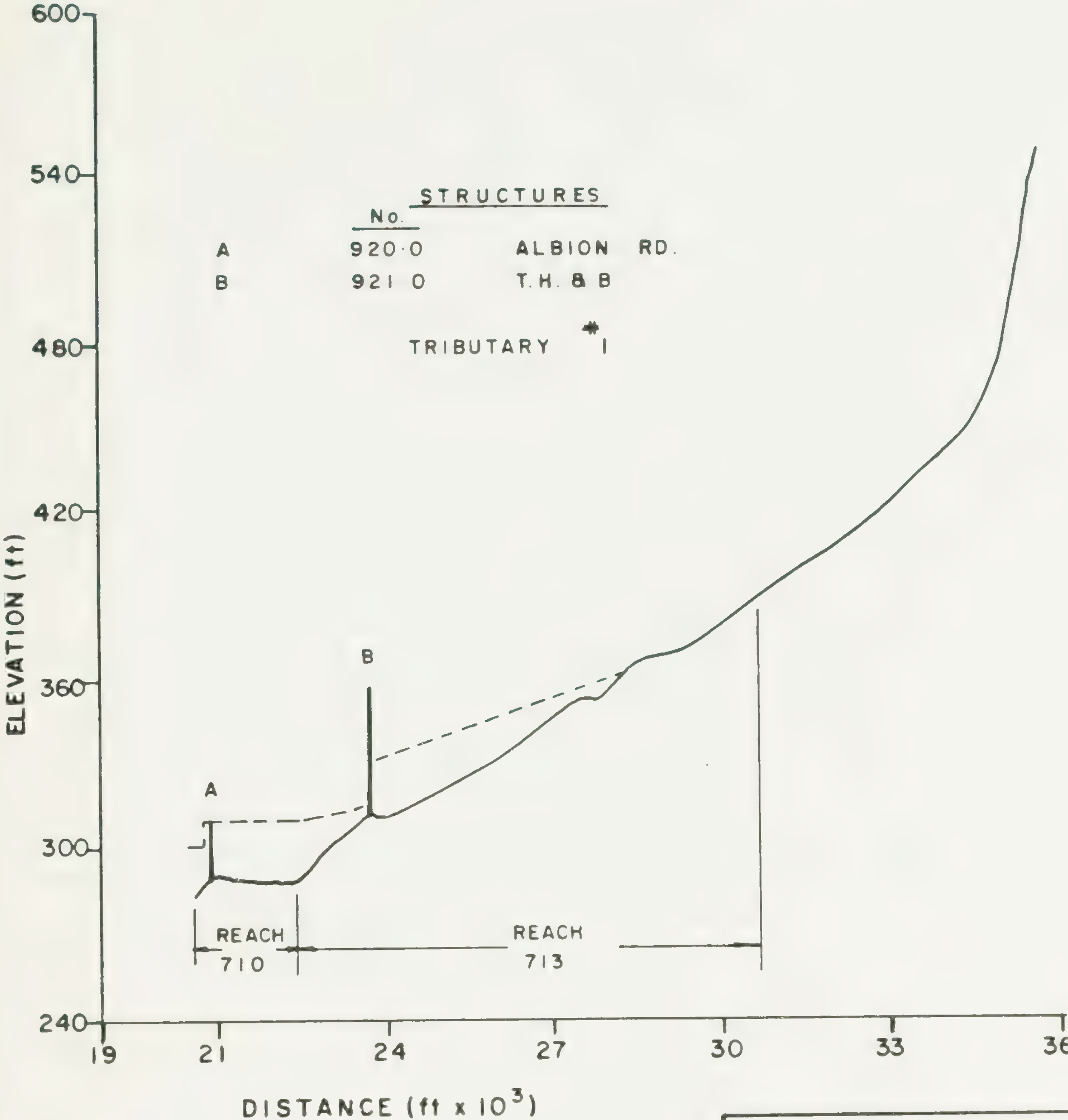
- The method of hydrologic analysis utilized in the watershed modelling study is presented and discussed.
- The data base for the hydrologic analysis is discussed and presented.
- The method of hydraulic analysis is presented and discussed.
- The results of the hydrologic analysis are presented and evaluated.
- Conclusions and recommendations are presented.

1.2 Watershed Description

The Red Hill Creek watershed drains an area of 71.94 square kilometers located within the Regional Municipality of Hamilton-Wentworth. Portions of the following member municipalities, listed in order of relative area drained, lie within the watershed limits as depicted on Map No.'s 2a, 2b and 2c:

- City of Hamilton
- Town of Stoney Creek
- Township of Glanbrook
- Township of Binbrook

The creek originates on the Niagara escarpment through several tributaries, flows over the brink of the escarpment at several picturesque waterfalls and then through a deep valley to Windermere Basin where it empties into Hamilton Harbour very near the Q.E.W. Skyway bridge.

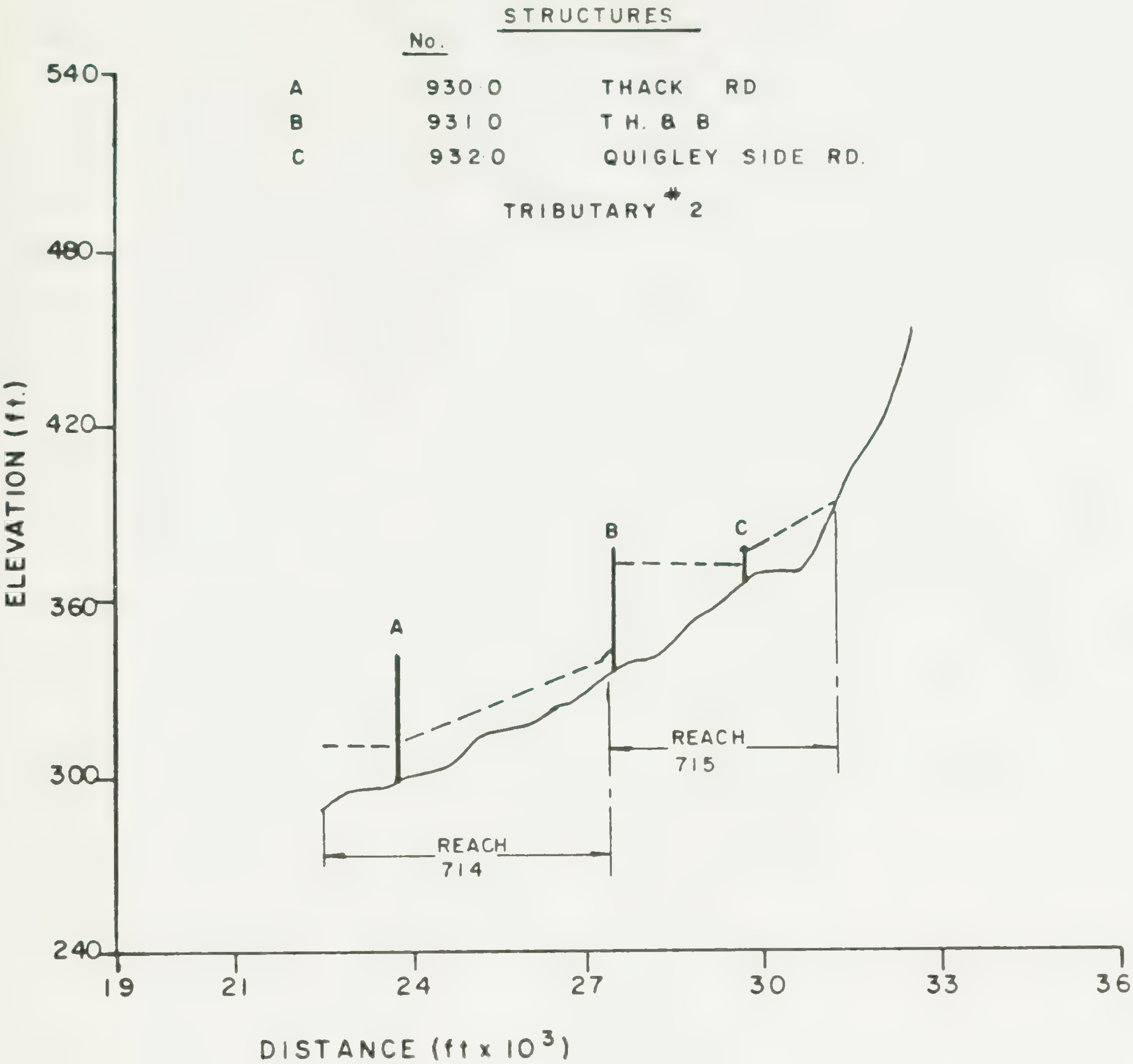


RED HILL CREEK
STORMWATER MANAGEMENT
STUDY

WATER SURFACE PROFILE
FOR TRIBUTARY # 1
100 YR FUTURE CONDITIONS
(NO CONTROLS)

DRAWING No. 2

Philips Planning Engineering Limited

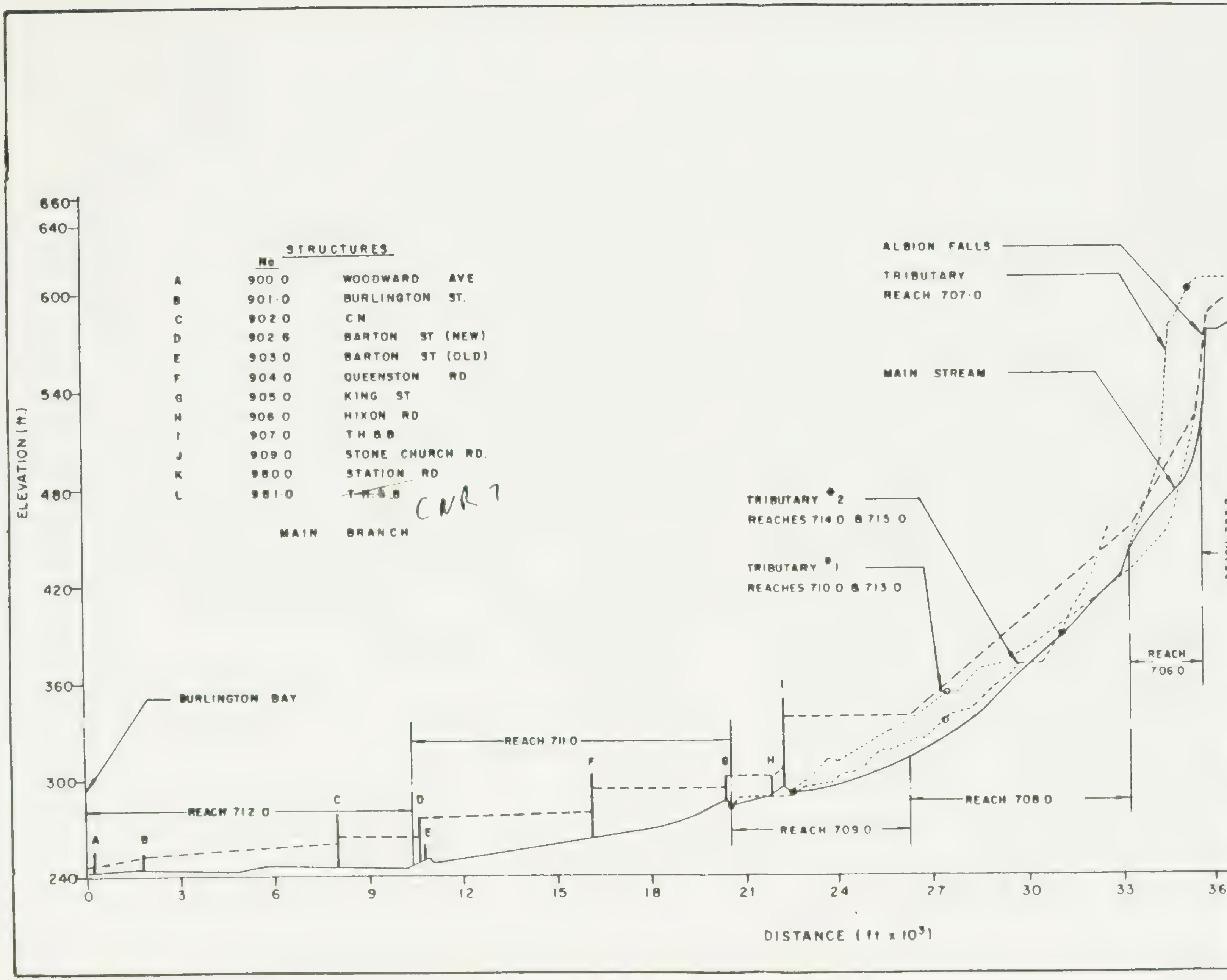


RED HILL CREEK STORMWATER MANAGEMENT STUDY

WATER SURFACE PROFILE FOR TRIBUTARY # 2
100 YR FUTURE CONDITIONS
(NO CONTROLS)

DRAWING No. 3

Philips Planning Engineering Limited



RED HILL CREEK
STORMWATER MANAGEMENT
STUDY

WATER SURFACE PROFILE
FOR MAIN STREAM
100 YR FUTURE CONDITIONS
(NO CONTROLS)

DRAWING No 1

In our study, we have considered the main stream to be that branch which runs northerly from Rymal Road (Highway No. 53) to the conservation area at Albion Falls where it cascades over the escarpment. From here it flows through the King's Forest area, passes under the TH&B Railway then crosses Queenston Road and Barton Street before passing alongside the Regional sewage and water treatment plants which are located near its mouth at Windermere Basin.

A major portion of Hamilton, lying above the escarpment is drained by two large tributaries which flow in an easterly direction until they meet the main stream.

The first of these flows roughly parallel to Limeridge Road, passes the Ottawa Street landfill site and meets the main stream a short distance upstream of Albion Falls. This branch has recently been mainly converted to a large box culvert trunk sewer 5.5 m by 4.6 m (18 ft. by 15 ft.) constructed to facilitate the future development of the Hamilton mountain area.

The second major tributary above the mountain runs as a trunk combined sewer, easterly along Fennell Avenue then over the escarpment and along Greenhill Avenue. This area has been almost totally developed and sewered for many years and during dry weather conditions all flow goes from Greenhill Avenue north to the sewage treatment plant. However, during periods of rainfall, much of the flow is bypassed to the main stream of Red Hill Creek near Greenhill Avenue. In order to minimize the detrimental impacts of these bypasses, the Region is presently constructing a very large holding tank (90,800 m^3) or 73.6 ac-ft. known as the Greenhill Storage Facility. It is intended that excess flow will be temporarily stored here and then treated during times of low flow. It is only during periods of very high flow that this storage tank would fill causing overflows to the creek to occur. This would occur during a design storm event such as the 5 Year Storm, but even then a significant portion of the runoff hydrograph would be captured and later treated.

Another large tributary system lies to the east of the main stream with two branches, one of which originates in the "Satellite City" area of Stoney Creek.

From here it flows to and over the brink of the escarpment at Felker's Falls then under the TH&B Railway embankment (reaches 715 and 714) to where it joins the other branch just downstream of Quigley Road. This other branch (Reach 713) flows alongside Albion Road and also crosses the TH&B Railroad. From here the combined eastern tributary (Reach 710) flows roughly parallel to the TH&B embankment a short distance westerly to the main stream.

Below the escarpment the creek and its easterly tributary flow through deeply incised valleys which are crossed by several high embankments, the greatest of which carries the TH&B Railroad. These embankments back flow up during major runoff events and act as very effective flood control reservoirs to significantly reduce peak flood flows in the downstream reaches.

Profiles of the stream and its major tributaries may be found on Drawing No's. 1, 2 and 3 which follow. Map No's. 2a, 2b and 2c are included in the later sections of this report to facilitate discussion of the watershed modelling data and results which are referenced to them.

2.0 METHOD OF HYDROLOGIC ANALYSIS

Several water resources computer programs were used in this stormwater management study.

Runoff hydrographs from incremental sub areas or subcatchments were calculated using the SUBHYD program,[1,2] developed by Mr. Larry Thompson, M.A.Sc., P. Eng.

The ROUTE computer program, also developed by Mr. Thompson, was used to perform kinematic wave flow routing calculations on the subcatchment hydrographs as they are combined along the watershed's conveyance system in their respective major-minor flow paths. The ROUTE program allowed a dynamic major-minor drainage system routing analysis to be done on this watershed.

The U.S. Army Corps of Engineers HEC-2 program was used to develop backwater rating curves for the various natural stream reaches. By making use of these rating curves thus determined for the natural stream reaches the ROUTE program was able to take into account the backwater effects of various embankments on flood hydrographs.

2.1 Subcatchment Runoff Methodology

The comprehensive, conceptual SUBcatchment HYDrologic model (SUBHYD), was used to calculate subcatchment hydrographs throughout the Red Hill Creek watershed. The SUBHYD computer model is a deterministic simulation model intended to be applicable to both urban and rural, discrete and continuous simulations.[1, 2] The components of the hydrologic cycle which are modelled are depicted in Illustration No. 1.

Within the model a subcatchment is broken down into three sub-areas, each of which has a somewhat different response to rainfall. This subdivision is as follows:

- impervious area
- pervious area
- channel area

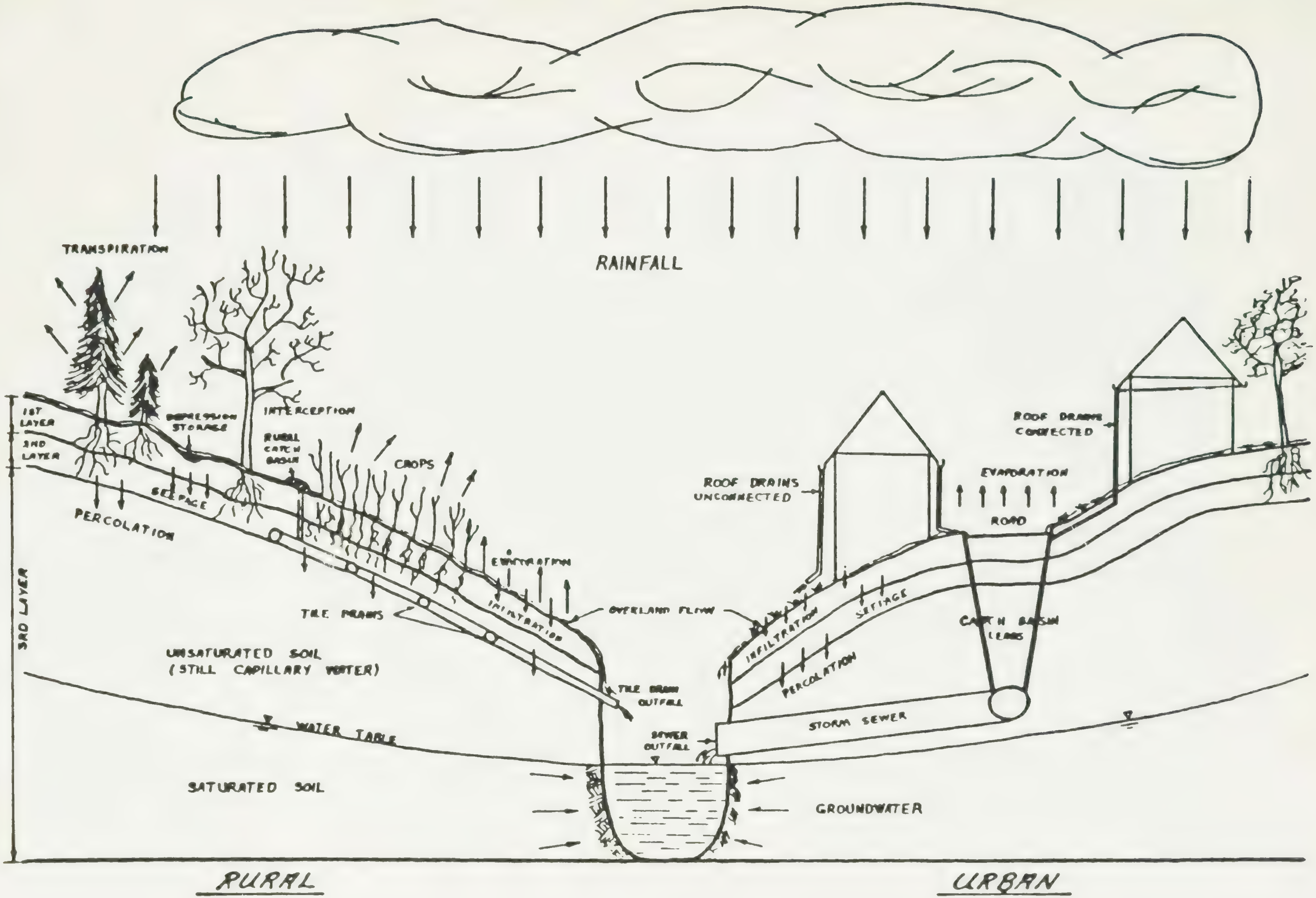


ILLUSTRATION NO. 1: COMPONENTS OF THE HYDROLOGIC CYCLE SIMULATED IN "SUBHYD"

A user specified portion of impervious area is allowed to drain onto pervious area bypassing interception. In this manner, the effect of roof drains discharging onto grassed areas can be reasonably simulated. This feature also facilitates the modelling of a parking lot draining to a pervious area rather than to a catch basin.

The model has been programmed in such a way that variable time steps may be used for computational economy during continuous simulations. During periods of rainfall these time steps are fairly small in order to simulate sudden changes but once rainfall ends, time steps may be increased in order to achieve computational economy.

The model calculates and prints out the following flow hydrographs where applicable for any subcatchment:

- runoff from channel precipitation
- impervious runoff
- pervious runoff
- tile drain outflow
- groundwater flow

These are added to give total flow from the subcatchment and comparisons may be made to observed flow hydrographs if such are available.

On various test simulations for both an urban and a rural subcatchment the model has been found to produce results which compare favourably with those obtained by two other hydrologic models known as SWMM[4] and HYMO.[5] The SUBHYD was also tested on the Hamilton Test Catchment[3] located within the watershed which is discussed in the Phase A report for this study.

2.2 Major-Minor System Flow Routing Methodology

2.2.1 Discussion and Definitions

During a storm an excess depth of water builds up on the land surface and begins to flow to and then along the nearest ditch, storm sewer or stream. These sewers, ditches and stream low-flow channels comprise what is known as the "minor" conveyance system. The term "minor" is used because all flow from small or minor runoff events travels along them.

When the capacity of the minor system is exceeded during a very large or "major" runoff event, excess flow travels down the "major" conveyance system. The major system normally consists of roadways, overflow channels or swales, and floodplains along streams. It must be remembered that a major conveyance system always exists even if it was not planned for. Where the path and extent of a major flow system has been left to chance however, some components of the system may be unacceptable. An example would be the case of an unlucky homeowner who happens to have a flood prone sunken driveway leading to a basement garage. In this case part of the major conveyance system would consist of his basement, which would function as a retention pond.

Thus the minor drainage system is a convenience system and functions during every runoff event. In contrast the major system is an overload system which functions whenever the minor system is either overloaded or blocked. A properly designed major system acts as an "overflow" for the minor system.

Hydrologic analysis of a conveyance system is done by means of flow routing calculations. These calculations allow for the time that it takes for flow to travel along a section or "reach" of the conveyance system and also for the fact that some of the flow goes into storage along the reach. This storage is simply the volume of water required to fill the flow carrier to a depth sufficient to produce a given outflow. These storage and travel or lag time effects combine to produce hydrograph attenuation.

An inflow hydrograph to a reach is attenuated when it is "lagged" and "flattened" somewhat through routing to produce the outflow hydrograph from the reach.

Normally a minor system is fairly hydraulically efficient and induces little attenuation in the routed hydrograph. The major system however, usually has significant ponding and in extreme cases major design peak flows may be reduced by as much as 50% when storage is taken into account. It is frequently found that minor system velocities are roughly twice that of the major system.

Since the velocities and therefore the attenuative effects of the major and minor systems are normally very different, it is vital that the geometry of each system be represented separately in an analysis. It is also necessary to model the dynamic separation of flow into the major and minor systems. This is particularly important when only portions of the minor system are overloaded. In this case flow may split into major and minor systems in one reach, be recombined as minor flow only in the next reach and then split again at another downstream reach.

2.2.2 Methodology Used

In the preceding section the characteristics of major-minor flow systems were discussed. In view of this discussion, the following desirable specifications of a major-minor system routing analysis may be set forth.

(1) constant travel time through either system should not be assumed

(2) there should be a dynamic split of flow into the major and minor systems

(3) flow routing calculations should be carried out separately and simultaneously for both systems.

Mr. Larry R. Thompson, M.A.Sc., P. Eng., has developed a computer program known as "ROUTE" which fulfills the above specifications and features kinematic wave flow routing.

The "ROUTE" program interfaces with the previously described "SUBHYD" program and was used to model the major-minor flow system within the Red Hill Creek watershed.

In the storm sewered reaches (Reach 501 to 510), the backup from these storm sewers into the major system was assumed to flow down either a roadway or an overland swale as appropriate (see Table 6 for details).

2.3 Stream Valley Flood Routing Methodology

2.3.1 Necessity of Accounting for Storage

In a drainage basin such as the Red Hill Creek which has constrictions along its channel due to culverts in embankments, backwater storage effects become important. Each embankment with its associated culvert acts like a dam, backing up water and creating in effect, a flood storage reservoir during high flow conditions.

If these storage effects are safe but not properly accounted for in a hydrologic analysis, peak flow estimations will be unrealistically high. This in turn will likely lead to recommendations for overly extensive channel and culvert improvements and thus unnecessarily high expenditures of public funds.

2.3.2 Method of Accounting for Valley Storage

A mathematical process of flood routing was used to account for the effect of valley storage on peak flood flows.

Very often these computations are based upon uniform flow assumptions. However, as noted, in the Red Hill Creek watershed there are numerous high embankments which with their associated culverts tend to back water up and act as flood control reservoirs during the storm.

These effects were taken into account in the following manner. For that part of the watershed having a HEC-2 data set (i.e. stream reaches 701 to 715), a series of water surface profiles were calculated using the HEC-2 program. Through this process, backwater rating curves were established for each section. Machine drawn plots of these rating curves were produced and are appended under separate cover. These rating curves were aggregated for each section and input to the ROUTE program so that the routing calculations performed took into account backwater effects of the structures. Through this procedure, in effect, a steady-state approximation of dynamic wave routing was attained.

Stream channel routing calculations based upon uniform flow assumptions were performed for Reach 601 and 601.1 as a valid HEC-2 data set was not available for these reaches.

2.4 Data Base

2.4.1 Sources of Data

This stormwater management study covered in detail the area within the Red Hill Creek watershed in the City of Hamilton (see Map No's. 2a, 2b and 2c).

From the topographic maps and from plans supplied to us by the City of Hamilton, the watershed was discretized into subcatchments and routing reaches and various data items were extracted. This discretization was discussed with Mr. Konrad Brenner, P. Eng., of the Regional Municipality of Hamilton-Wentworth.

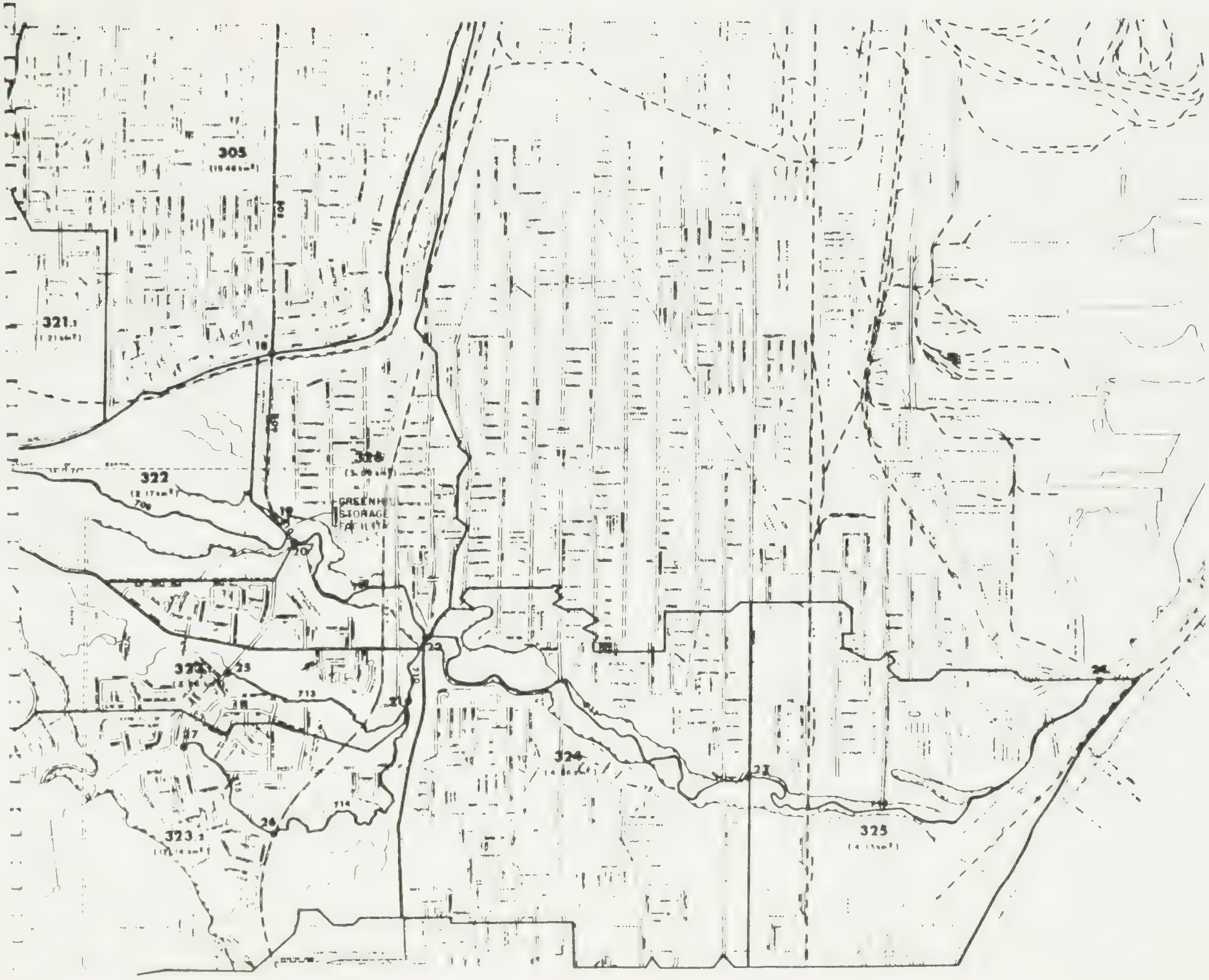
A series of field investigations were undertaken in order to gain first-hand knowledge of the drainage pattern. Photographs of most culverts, areas of interest and typical terrain were also taken during the field investigation.

With the drainage system decided and the study area broken up into subcatchments, both the subcatchment hydrologic data and the flow routing data was determined according to the SUBHYD and ROUTE computer program format. With this data, the major and minor flow design flows were calculated at various locations throughout the Red Hill Creek watershed.

2.4.2 SUBHYD Subcatchment Data

The following hydrologic data items are required for the SUBHYD computer program for each subcatchment:

- area
- percent impervious surfaces



LEGEND

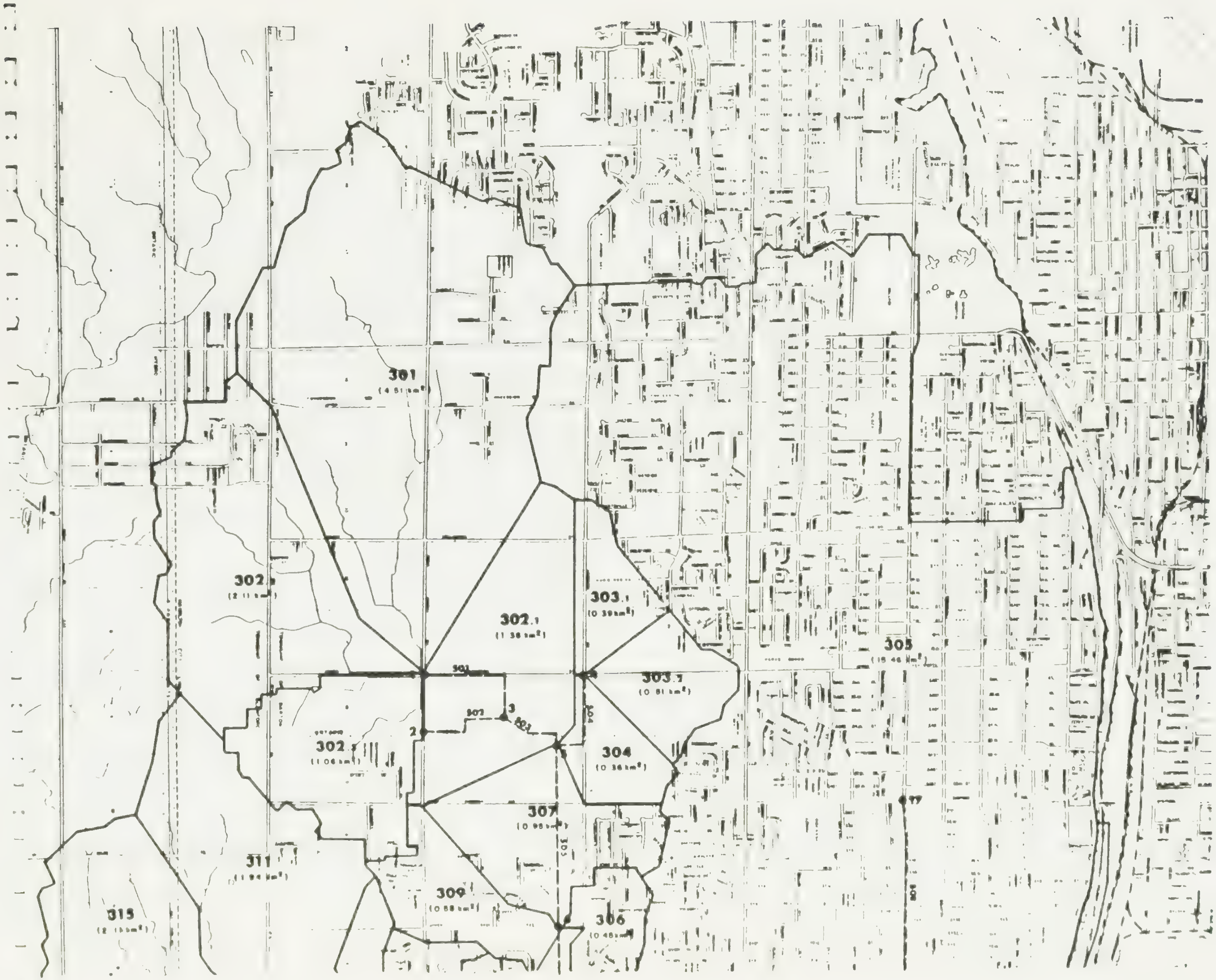
———	SUBCATCHMENT BOUNDARY
321	SUBCATCHMENT NUMBER
• 16	ROUTING NODE NUMBER
701	NATURAL STREAM ROUTING REACH
301	SEWERED ROUTING REACH
901	COMBINATION NATURAL STREAM AND SEWERED ROUTING REACH

RED HILL CREEK

STORMWATER MANAGEMENT STUDY

MODELLING LAYOUT OF STUDY AREA

MAP 2A



LEGEND

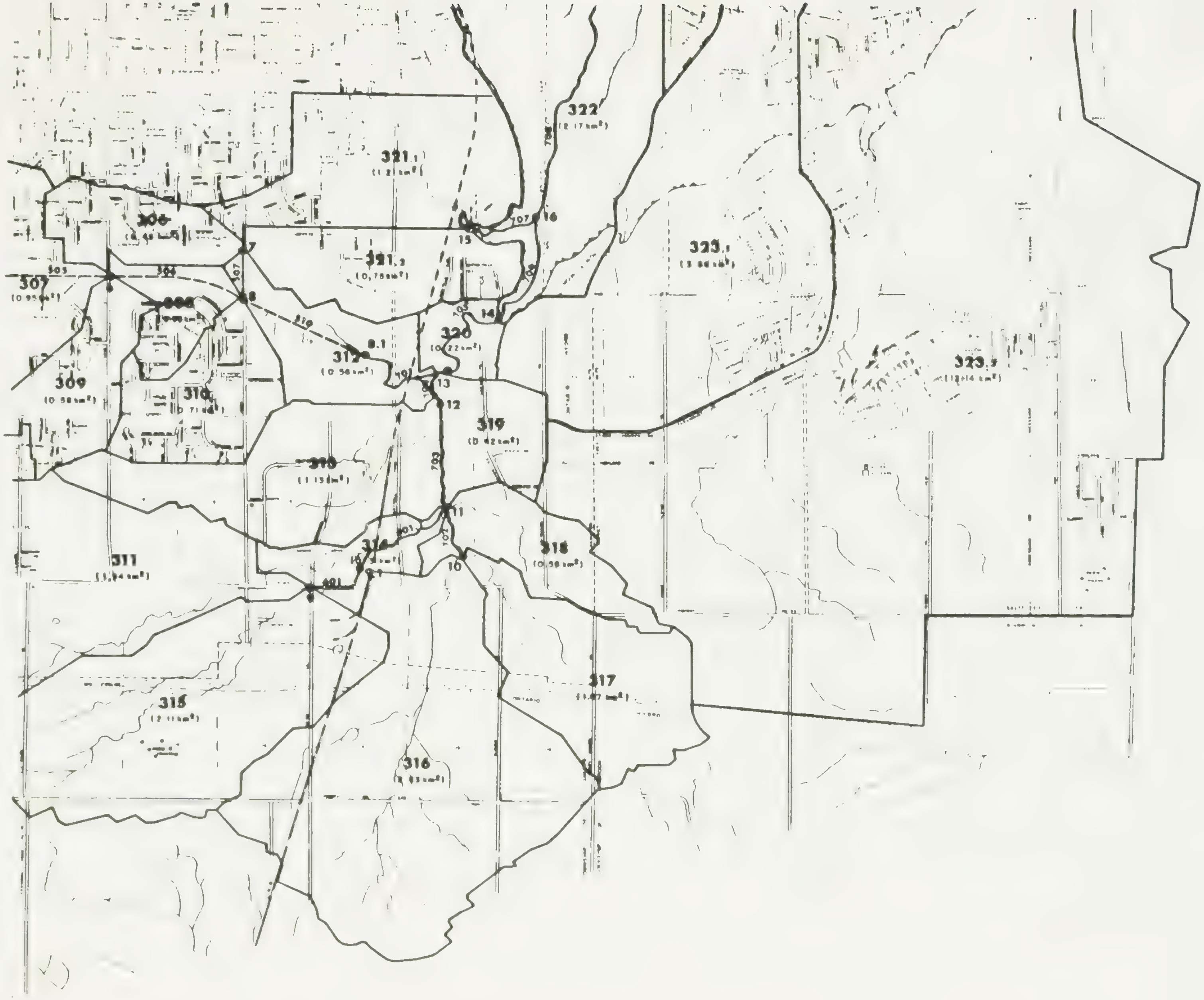
——	SUBCATCHMENT BOUNDARY
321	SUBCATCHMENT NUMBER
● 16	ROUTING NODE NUMBER
701	NATURAL STREAM ROUTING REACH
501	SEWERED ROUTING REACH
601	COMBINATION NATURAL STREAM AND SEWERED ROUTING REACH

RED HILL CREEK

STORMWATER MANAGEMENT STUDY

MODELLING LAYOUT OF STUDY AREA

MAP 2B



LEGEND

———	SUBCATCHMENT BOUNDARY
321	SUBCATCHMENT NUMBER
● 16	ROUTING NODE NUMBER
701	NATURAL STREAM ROUTING REACH
501	SEWERED ROUTING REACH
601	COMBINATION NATURAL STREAM AND SEWERED ROUTING REACH

RED HILL CREEK

STORMWATER MANAGEMENT STUDY

MODELLING LAYOUT OF STUDY AREA

MAP 2C

- impervious overland flow length
- pervious overland flow length
- pervious and impervious Manning's "N" for overland flow
- weighted ground slope
- various vegetation information
  - type
  - percentage in each catchment
  - root depth
  - growth index
  - crop depression storage
  - crop interception
- percent impervious area running onto pervious area
- weighted soil data for each catchment for three soil layers deep.

The percent impervious surfaces are that percent of the subcatchment on which infiltration does not occur. This includes roads, sidewalks, stream channels and roofs having drains connected to storm sewers. The actual lengths and widths of all roadways were measured from maps. Typical roof areas were determined and then multiplied by the number of such residences. Large residence roof and parking lot areas were individually measured.

Impervious overland flow length was estimated using the topographic mapping. This length is the average flow distance in a subcatchment from the impervious surface to the flow carrier plus the average flow distance out of the catchment via the flow carrier.

The pervious overland flow length was also estimated using the 1" = 800' topographic mapping of the watershed. The pervious flow length is the average maximum distance which pervious overland flow must travel to a flow carrier plus the average distance down the pervious flow carrier out of the catchment. The latter distance down the pervious flow carrier out of the catchment was also weighted by the ratio of the pervious overland "N" to the flow carrier "N".

The values of Manning's "N" to be used for incremental overland flow calculations for both pervious and impervious areas were selected according to reference 1 and the SWMM user's manual, and originate from work done by Ray K. Linsley with the Stanford Watershed Model. For example, a value of 0.013 was used for impervious areas and for residential lawns, 0.25 was used.

The vegetative information was weighted for each catchment and derived from topographic mapping and the landuse within the study area according to reference 1.

The percent impervious area running onto pervious area as required in the SUBHYD computer model was set as O for this study as roof drains were considered to discharge 100% to storm sewers.

The soils information was obtained from the soil survey of Wentworth County (Report No. 32 of the Ontario Soil Survey), Department of Agriculture, Toronto, Ottawa. Soils information was collected three soil layers deep and was weighted for each subcatchment according to reference 1.

The values of these hydrologic parameters used for each subcatchment are summarized in Tables 5, 6 and 7.

2.4.3 Routing Data

The major and minor flow path for each subcatchment was determined using photographs, field investigation and information from the various supplied maps and plans of the City of Hamilton.

The following data are required by the ROUTE computer program for each subcatchment:

- system connectivity
- flow divider value and/or scheme

TABLE NO. 5: SUBCATCHMENT DATA - FOR "SUBHYD" COMPUTER PROGRAM

SUB-CATCHMENT	AREA (Km^2)	IMPERVIOUS AREA DATA: % IMPERVIOUS	% IMPERVIOUS DRAINING TO PERVIOUS	OVERLAND FLOW "N"	DEPRESSION STORAGE (CM)	REPRESENTATIVE MAX. OVERLAND FLOW LENGTH (M)	SLOPE (M/M)	PERVIOUS AREA DATA: OVERLAND FLOW "N"	DEPRESSION STORAGE (CM)	REPRESENTATIVE MAX. OVERLAND FLOW LENGTH (M)	SLOPE (M/M)	SOIL TYPES (LOAM) AND PERCENTAGES	LAND USES AND PERCENTAGES
314	0.31	5.9	0	0.013	0.157	131.0	0.0125	0.28	0.51	107.0	0.0125	Oneida Silty = 32 Farmington = 68	Medium Length Grass = 100
315	2.11	1.9	0	0.013	0.157	192.0	0.0121	0.28	0.51	129.0	0.0121	Smithville Silty = 36 Beverly Silty Clay = 26 Oneida Silty = 22 Binbrook Silty = 15 Farmington = 1	Medium Length Grass = 100
316	2.83	2.7	0	0.013	0.157	242.0	0.0227	0.28	0.51	163.0	0.0227	Oneida Silty = 43 Beverly Silty = 17 Binbrook Silty = 18 Beverly Silty Clay = 4 Toledo Silty Clay = 12 Smithville Silty = 7 Farmington = 3	Medium Length Grass = 100
317	1.07	2.7	0	0.013	0.157	198.0	0.0200	0.28	0.51	82.0	0.0200	Smithville Silty = 47 Oneida Silty = 30 Beverly Silty = 16 Binbrook Silty = 7	Medium Length Grass = 100
318	0.96	3.5	0	0.013	0.157	146.0	0.0176	0.28	0.51	99.0	0.0176	Oneida Silty = 44 Chinguacousy Silty = 29 Smithville Silty = 27	Medium Length Grass = 100
319	0.42	8.8	0	0.013	0.157	88.0	0.0154	0.28	0.51	100.0	0.0154	Chinguacousy Silty = 40 Oneida Silty = 60	Medium Length Grass = 98 Woods = 2
320	0.22	3.8	0	0.013	0.157	65.0	0.0571	0.28	0.51	137.0	0.0571	Oneida Silty = 100	Residential Lawn = 80 Medium Length Grass = 15 Woods = 5
321.1	1.21	9.6	0	0.013	0.157	136.0	0.0088	0.27	0.49	132.5	0.0088	Haldimand Silty = 68 Oneida Silty = 26 Escarpment = 6	Residential Lawn = 30 Medium Length Grass = 68 Woods = 2
321.2	0.75	16.0	0	0.013	0.157	80.0	0.0091	0.28	0.50	76.0	0.0091	Haldimand Silty = 55 Oneida Silty = 42 Escarpment = 3	Residential Lawn = 30 Medium Length Grass = 60 Woods = 10
322	2.17	1.5	0	0.013	0.157	464.0	0.0478	0.40	0.60	251.0	0.0478	Oneida = 67 Escarpment = 17 Grimsby Sandy = 13 Winona Sandy = 3	Woods = 70 Medium Length Grass = 15 Residential Lawn = 15
323.1	3.86	13.0	0	0.013	0.157	999.0	0.0248	0.27	0.50	333.0	0.0248	Oneida = 31 Oneida Silty = 23 Grimsby Sandy = 16 Haldimand Silty = 10 Chinguacousy Silty = 7 Winona Sandy = 7 Alberton Silty = 4 Escarpment = 3 Binbrook Silty = 1	Residential Lawn = 30 Medium Length Grass = 65 Woods = 5
323.2	12.10	3.5	0	0.013	0.157	648.0	0.0259	0.27	0.50	338.0	0.0259	Oneida = 16 Smithville Silty = 15 Haldimand Silty = 12 Farmington = 6 Binbrook Silty = 3 Lincoln Silty Clay = 3 Chinguacousy Silty = 2 Oneida Silty = 3 Escarpment = 2 Toledo Silty = 2 Toledo Silty Clay = 2 Beverly Silty = 1 Burford = 1	Residential Lawn = 30 Medium Length Grass = 65 Woods = 5
324	4.66	26.0	0	0.013	0.157	251.0	0.0111	0.27	0.49	179.0	0.0111	Winona Sandy = 64 Grimsby Sandy = 27 Burford = 9	Residential Lawn = 70 Medium Length Grass = 25 Woods = 5
325	4.13	16.0	0	0.013	0.157	360.0	0.0100	0.28	0.51	201.0	0.0100	Winona Sandy = 62 Grimsby Sandy = 35 Vineland Sandy = 3	Medium Length Grass = 65 Residential Lawn = 30 Woods = 5
326	3.09	12.5	0	0.013	0.157	193.0	0.0136	0.29	0.50	121.0	0.0136	Oneida = 59 Grimsby Sandy = 31 Escarpment = 10	Woods = 59 Medium Length Grass = 10 Residential Lawn = 31

TABLE NO. 5: SUBCATCHMENT DATA - FOR "SUBHYD" COMPUTER PROGRAM

SUB-CATCHMENT	AREA (Km^2)	IMPERVIOUS AREA DATA: % IMPERVIOUS	% IMPERVIOUS DRAINING TO PERVIOUS	OVERLAND FLOW "N"	DEPRESSION STORAGE (CM)	REPRESENTATIVE MAX. OVERLAND FLOW LENGTH (M)	SLOPE (M/M)	PERVIOUS AREA DATA: OVERLAND FLOW "N"	DEPRESSION STORAGE (CM)	REPRESENTATIVE MAX. OVERLAND FLOW LENGTH (M)	SLOPE (M/M)	SOIL TYPES (LOAM) AND PERCENTAGES	LAND USES AND PERCENTAGES
314	0.31	3.9	0	0.013	0.157	131.0	0.0125	0.28	0.51	107.0	0.0125	Oneida Silty = 32 Farmington = 68	Medium Length Grass = 100
315	2.11	1.9	0	0.013	0.157	192.0	0.0121	0.28	0.51	129.0	0.0121	Smithville Silty = 36 Beverly Silty Clay = 26 Oneida Silty = 22 Binbrook Silty = 15 Farmington = 1	Medium Length Grass = 100
316	2.83	2.7	0	0.013	0.157	262.0	0.0227	0.28	0.51	165.0	0.0227	Oneida Silty = 43 Beverly Silty = 17 Binbrook Silty = 14 Beverly Silty Clay = 4 Toledo Silty Clay = 12 Smithville Silty = 7 Farmington = 3	Medium Length Grass = 100
317	1.07	2.7	0	0.013	0.157	198.0	0.0200	0.28	0.51	82.0	0.0200	Smithville Silty = 47 Oneida Silty = 30 Beverly Silty = 16 Binbrook Silty = 7	Medium Length Grass = 100
318	0.56	3.3	0	0.013	0.157	146.0	0.0176	0.28	0.51	99.0	0.0176	Oneida Silty = 44 Chinguacousy Silty = 29 Smithville Silty = 27	Medium Length Grass = 100
319	0.42	8.8	0	0.013	0.157	88.0	0.0154	0.28	0.51	100.0	0.0154	Chinguacousy Silty = 40 Oneida Silty = 60	Medium Length Grass = 98 Woods = 2
320	0.22	3.8	0	0.013	0.157	65.0	0.0371	0.28	0.51	137.0	0.0371	Oneida Silty = 100	Residential Lawn = 80 Medium Length Grass = 15 Woods = 5
321.1	1.21	9.6	0	0.013	0.157	136.0	0.0088	0.27	0.49	132.0	0.0088	Haldimand Silty = 68 Oneida Silty = 26 Escarpment = 6	Residential Lawn = 50 Medium Length Grass = 48 Woods = 2
321.2	0.75	16.0	0	0.013	0.157	80.0	0.0091	0.28	0.50	76.0	0.0091	Haldimand Silty = 55 Oneida Silty = 42 Escarpment = 3	Residential Lawn = 50 Medium Length Grass = 40 Woods = 10
322	2.17	1.5	0	0.013	0.157	464.0	0.0478	0.40	0.60	231.0	0.0478	Oneida = 67 Escarpment = 17 Grimsby Sandy = 13 Winona Sandy = 3	Woods = 70 Medium Length Grass = 15 Residential Lawn = 15
323.1	3.86	13.0	0	0.013	0.157	599.0	0.0248	0.27	0.50	333.0	0.0248	Oneida = 31 Oneida Silty = 23 Grimsby Sandy = 18 Haldimand Silty = 10 Chinguacousy Silty = 7 Winona Sandy = 7 Alberton Silty = 4 Escarpment = 3 Binbrook Silty = 1	Residential Lawn = 50 Medium Length Grass = 45 Woods = 5
323.2	12.14	3.5	0	0.013	0.157	648.0	0.0259	0.27	0.50	338.0	0.0259	Oneida = 16 Smithville Silty = 15 Haldimand Silty = 12 Farmington = 6 Binbrook Silty = 3 Lincoln Silty Clay = 3 Chinguacousy Silty = 2 Oneida Silty = 3 Escarpment = 2 Toledo Silty = 2 Toledo Silty Clay = 2 Beverly Silty = 1 Burford = 1	Residential Lawn = 50 Medium Length Grass = 45 Woods = 5
324	4.66	26.0	0	0.013	0.157	251.0	0.0111	0.27	0.49	179.0	0.0111	Winona Sandy = 64 Grimsby Sandy = 27 Burford = 9	Residential Lawn = 70 Medium Length Grass = 25 Woods = 5
325	4.13	16.0	0	0.013	0.157	360.0	0.0100	0.28	0.51	241.0	0.0100	Winona Sandy = 62 Grimsby Sandy = 35 Vineland Sandy = 3	Medium Length Grass = 65 Residential Lawn = 30 Woods = 5
326	3.09	12.5	0	0.013	0.157	193.0	0.0156	0.29	0.50	121.0	0.0156	Oneida = 59 Grimsby Sandy = 31 Escarpment = 10	Woods = 59 Medium Length Grass = 10 Residential Lawn = 31

TABLE NO. 6 : PERVIOUS LAND USE DATA

LAND USE	HOLTON'S "A" FACTOR	DEPRESSION STORAGE (CM)	OVERLAND FLOW "N"	RATIO OF EVAPOTRANSPIRATION TO PAN EVAPORATION	ROOT DEPTH (CM)	GROWTH INDEX	LEAF STORAGE (CM)	HORTON'S "B" FACTOR	AREAL PROJECTION FACTOR
Residential Lawn	1.0	0.47	0.25	1.0	7.62	0.98	0.002	0.013	1.0
Medium Length Grass	0.95	0.51	0.28	1.0	10.16	0.96	0.003	0.02	1.0
High Length Grass	0.90	0.64	0.30	1.0	12.7	0.95	0.004	0.027	1.0
Idle Land (Field)	0.40	0.64	0.35	1.0	91.44	0.93	0.025	0.16	1.0
Corn	0.20	0.64	0.13	1.5	60.96	0.67	0.064	0.025	0.50
Hay	0.40	0.64	0.35	1.2	76.2	0.95	0.038	0.30	1.0
Woods	0.90	0.64	0.45	2.0	152.4	1.0	0.076	0.18	0.95

TABLE NO. 7: SOIL DATA

SOIL NAME	SOIL LAYER	TEXTURAL CLASSIFICATION	GRAVITY STORAGE (%)	CAPILLARY STORAGE (%)	SOIL DEPTH (cm)	PERMEABILITY (cm/hr)
Grimsby	1	Sandy Loam	18.6	12.3	20.0	12.7
	2	Loamy Sand	26.9	10.1	33.0	66.0
	3	Sandy Loam	18.6	12.3	300.0	12.7
Vineland	1	Sandy Loam	18.6	12.3	13.0	12.7
	2	Sandy Loam	18.6	12.3	38.0	12.7
	3	Sandy Loam	18.6	12.3	300.0	12.7
Burford	1	Loam	14.4	15.6	30.0	5.0
	2	Sandy Loam	18.6	12.3	11.0	12.7
	3	Gravelly Loam	15.8	8.7	300.0	6.9
Winona	1	Sandy Loam	18.6	12.3	18.0	12.7
	2	Loamy Sand	26.9	10.1	35.0	66.0
	3	Silty Clay	9.1	12.3	300.0	2.1
Beverly	1	Silt Loam	11.4	19.9	23.0	3.2
	2	Silty Clay Loam	8.4	14.9	23.0	1.8
	3	Silty Clay Loam	8.4	14.9	300.0	1.8
Escarpment	1	Silt Loam	11.4	19.9	23.0	3.2
	2	Silty Clay Loam	8.4	14.9	7.6	1.8
	3	Bedrock	0.5	0.001	300.0	0.100
Oneida	1	Silt Loam	11.4	19.9	15.0	3.2
	2	Silty Clay Loam	8.4	14.9	26.0	1.8
	3	Silty Clay	9.1	12.3	300.0	2.1

TABLE NO. 7: SOIL DATA

SOIL NAME	SOIL LAYER	TEXTURAL CLASSIFICATION	GRAVITY STORAGE (%)	CAPILLARY STORAGE (%)	SOIL DEPTH (cm)	PERMEABILITY (cm/hr)
Toledo	1	Silt Loam	11.4	19.9	20.0	3.2
	2	Silty Clay Loam	8.4	14.9	26.0	1.8
	3	Silty Clay	9.1	12.3	300.0	2.1
Brantford	1	Silt Loam	11.4	19.9	23.0	3.2
	2	Silt Loam	11.4	19.9	13.0	3.2
	3	Silty Clay	9.1	12.3	300.0	2.1
Brant-Grim Complex	1	Silt Loam + Sandy Loam	15.0	16.1	21.0	6.1
	2	Silt Loam + Loamy Sand	19.2	15.0	24.0	14.7
	3	Silty Clay + Sandy Loam	13.9	12.3	300.0	4.6
Chinguacousy	1	Silty Clay Loam	8.4	14.9	23.0	1.8
	2	Clay Loam	13.0	12.7	13.0	3.8
	3	Silty Clay Loam	8.4	14.9	300.0	1.8
Oneida	1	Loam	14.4	15.6	15.0	5.0
	2	Silty Clay Loam	8.4	14.9	26.0	1.8
	3	Silty Clay	9.1	12.3	300.0	2.1
Alberton	1	Silt Loam	11.4	19.9	20.0	3.2
	2	Silty Clay Loam	8.4	14.9	26.0	1.8
	3	Silty Clay Loam	8.4	14.9	300.0	1.8
Lincoln	1	Silty Clay Loam	8.4	14.9	15.0	1.8
	2	Clay	7.3	11.5	23.0	1.4
	3	Clay Till	7.3	11.5	300.0	1.4

- minor routing reach data
  - length
  - Manning's "N"
  - bed slope
  - side slopes
  - diameter or bottom width
  - reach type
- major routing reach data
  - length
  - Manning's "N"
  - bed slope
  - side slopes
  - diameter or bottom width
  - reach type

The system connectivity was established with regard to the tributary reaches and subcatchments of each of the major and minor flow paths within the Red Hill Creek watershed boundary of the City of Hamilton. The routing node and reach locations are identified on Map No's. 2a, 2b and 2c.

Division of inflow into major and minor systems may be done in several ways with the ROUTE program, according to the value of a parameter known as a flow divider.

(a) all flow less than a specified value will be sent to minor system (inlet control) while excess will flow along major system. This value may be calculated by the program as being equal to the conduit capacity.

(b) flow may be split on a fractional basis between the systems. (e.g. 30% to minor and 70% to major).

(c) all flow may be directed to minor system but upon minor system storage being exhausted (i.e. pipes full) any excess will be backed up and overflowed to major system.

(d) major and minor systems may be seen to be combined as in the case of a natural stream reach with rating curves available.

For this study options (c) and (d) were used as and where applicable.

The minor and major routing reach data were determined according to the photographs of the reaches and from storm sewer information supplied to us from the City of Hamilton. The reach type could be either a circular or trapezoidal shaped section. The values of these routing parameters for each reach are summarized in Table 8.

2.4.4 Future Landuse Conditions

The Red Hill Creek was initially modelled in its existing state of development. In order to determine the impact of future urbanization on flood flows in the creek it was necessary to model the watershed for anticipated future conditions.

This was accomplished through reference to the City of Hamilton zoning by-law[13] and through discussion with Mr. Konrad Brenner, P. Eng., of the Hamilton-Wentworth Engineering Department.

For modelling purposes the following modelling landuse classes, associated zoning by-law classes and design % imperviousness were considered (see Table 9).

The modelling landuse class "mixed residential" was used for those areas where future development was expected but where land was not presently zoned for it. This included major portions of land on the escarpment, both in Hamilton and Stoney Creek. A representative % imperviousness to use for this class was determined with reference to the following five neighbourhood plans which have been proposed in this area:

- Templemead
- Rushdale
- Quinndale
- Eleanor
- Randall

TABLE NO. 8 : ROUTING DATA

REACH NO.	TRIB. CATCH-MENTS	TRIB. REACHES	FLOW DIVIDER VALUE (cms)	MINOR ROUTING REACH						MAJOR ROUTING REACH					
				CARRIER TYPE	LENGTH (m)	MANNING'S "N"	BED SLOPE (m/m)	SIDE SLOPES (Hor/Vert)	DIA.OR BOTTOM WIDTH (m)	CARRIER TYPE	LENGTH (m)	MANNING'S "N"	BED SLOPE (m/m)	SIDE SLOPES (Hor/Vert)	DIA.OR BOTTOM WIDTH (m)
501	301 302.2	-	*	T	627.0	0.013	0.0018	-	4.877	T	627.0	0.030	0.0018	2.0	3.0
502	302.3	-	*	C	442.0	0.013	0.003	-	2.286	T	442.0	0.030	0.003	2.0	1.0
503	302.1	501 502	*	T	411.0	0.013	0.002	-	5.486	T	411.0	0.030	0.002	4.0	3.0
504	303.1 303.2	-	*	C	610.0	0.013	0.003	-	1.980	T	610.0	0.013	0.003	50.0	0.5
505	304	503 504	*	T	1219.0	0.013	0.002	-	5.486	T	1219.0	0.025	0.002	5.0	3.0
506	307 309 308	505	*	T	948.0	0.013	0.002	-	5.486	T	948.0	0.025	0.002	5.0	3.0
507	306	-	*	C	130.0	0.013	0.005	-	1.524	T	130.0	0.013	0.005	50.0	0.5
508	-	508.1	*	T	1372.0	0.013	0.005	-	3.505	T	1372.0	0.013	0.005	50.0	0.5
508.1	305	-	*	T	1371.0	0.013	0.005	-	3.505	T	1371.0	0.013	0.005	50.0	1.0
509	-	508.0	*	T	1067.0	0.013	0.010	-	3.048	T	1067.0	0.013	0.010	50.0	0.5

NOTE: FOR REACH LOCATIONS SEE MAPS 2A, 2B AND 2C

CARRIER TYPE T TRAPEZOID C CIRCULAR RC RATING CURVE

*OVERFLOW TO MAJOR SYSTEM WHEN MINOR SYSTEM STORAGE FULL

TABLE NO. 8: ROUTING DATA

REACH NO.	TRIB. CATCH-MENTS	TRIB. REACHES	FLOW DIVIDER VALUE (cms)	MINOR ROUTING REACH						MAJOR ROUTING REACH					
				CARRIER TYPE	LENGTH (m)	MANNING'S "N"	BED SLOPE (m/m)	SIDE SLOPES (Hor/Vert)	DIA.OR BOTTOM WIDTH (m)	CARRIER TYPE	LENGTH (m)	MANNING'S "N"	BED SLOPE (m/m)	SIDE SLOPES (Hor/Vert)	DIA.OR BOTTOM WIDTH (m)
510	310	506 507	*	T	610.0	0.013	0.002	-	6.706	T	610.0	0.025	0.002	5.0	3.0
601	311 315	-	*	C	503.0	0.013	0.002	-	3.658	T	503.0	0.025	0.002	5.0	3.0
601.1	314	601.0	*	T	564.0	0.035	0.007	3.46	1.0	T	564.0	0.035	0.007	50.0	7.92
701	312	510	-	RC	1112.0	-	-	-	-	T	1112.0	0.025	0.005	2.0	2.0
702	316	-	-	RC	305.0	-	-	-	-	T	305.0	0.025	0.005	2.0	2.0
703	318	601.1 702	-	RC	488.0	-	-	-	-	T	488.0	0.025	0.005	2.0	2.0
704	313 319	701 703	-	RC	549.0	-	-	-	-	T	549.0	0.025	0.005	2.0	2.0
705	-	704	-	RC	457.0	-	-	-	-	T	457.0	0.025	0.005	2.0	2.0
706	320	705	-	RC	670.0	-	-	-	-	T	670.0	0.025	0.005	2.0	2.0
707	321.1 321.2	-	-	RC	518.0	-	-	-	-	T	518.0	0.025	0.005	2.0	2.0

NOTE: FOR REACH LOCATIONS SEE MAPS 2A, 2B AND 2C

CARRIER TYPE T TRAPEZOID C CIRCULAR RC RATING CURVE

*OVERFLOW TO MAJOR SYSTEM WHEN MINOR SYSTEM STORAGE FULL

TABLE NO. 8: ROUTING DATA

REACH NO.	TRIB. CATCH-MENTS	TRIB. REACHES	FLOW DIVIDER VALUE (cms)	MINOR ROUTING REACH CARRIER TYPE	LENGTH (m)	MANNING'S "N"	BED SLOPE (m/m)	SIDE SLOPES (Hor/Vert)	DIA.OR BOTTOM WIDTH (m)	MAJOR ROUTING REACH CARRIER TYPE	LENGTH (m)	MANNING'S "N"	BED SLOPE (m/m)	SIDE SLOPES (Hor/Vert)	DIA.OR BOTTOM WIDTH (m)
708	322	706 707	-	RC	1545.0	-	-	-	-	T	1545.0	0.025	0.005	2.0	2.0
709	326	708 801	-	RC	1750.0	-	-	-	-	T	1750.0	0.025	0.005	2.0	2.0
710	-	713 714	-	RC	503.0	-	-	-	-	T	503.0	0.025	0.005	2.0	2.0
711	324	709 710	-	RC	2713.0	-	-	-	-	T	2713.0	0.025	0.005	2.0	2.0
712	325	711	*	T	1.0	0.030	0.005	2.0	2.0	T	1.0	0.030	0.005	2.0	2.0
712.1	-	712	*	T	1.0	0.030	0.005	2.0	2.0	T	1.0	0.030	0.005	2.0	2.0
713	323.1	-	-	RC	1326.0	-	-	-	-	T	1326.0	0.025	0.005	2.0	2.0
714			-	RC	1387.0	-	-	-	-	T	1387.0	0.025	0.005	2.0	2.0
715	323.2	-	-	RC	930.0	-	-	-	-	T	930.0	0.025	0.005	2.0	2.0
801	-	509	*	RC	100.0	-	-	-	-	T	1.0	0.013	0.010	5.0	2.0

NOTE: FOR REACH LOCATIONS SEE MAPS 2A, 2B AND 2C

CARRIER TYPE T TRAPEZOID C CIRCULAR RC RATING CURVE

*OVERFLOW TO MAJOR SYSTEM WHEN MINOR SYSTEM STORAGE FULL

*REACH 801 IS THE GREENHILL STORAGE FACILITY

TABLE NO. 9: MODELLING OF FUTURE LANDUSE

MODELLING LANDUSE CLASS	DESIGN % IMPERVIOUSNESS	ASSOCIATED CITY OF HAMILTON ZONING DESIGNATIONS
1. Agricultural, Open Space and Park	5	A, AA, F
2. Residential (Low Density)	30	C, D, DE, B, B-1, B-2
3. Residential (Mixed Density)	45	RT-10, RT-20, RT-30 Note: Used for areas where future development expected but where land is presently zoned for agricultural or open space characteristics based on 5 typical neighbourhood plans.
4. Residential (High Density)	75	E, E-1, E-2, E-3,
5. Commercial	90	CR-1, CR-2, CR-3, G, G-1, G-2, G-3, G-4, H, HH, I, HI
6. Industrial	75	J, JJ, K, KK, M-11, M-12, M-13, M-14, M-15

TABLE NO. 10

FULLY DEVELOPED % IMPERVIOUSNESS

FOR EACH SUBCATCHMENT

(EXISTING DRAINAGE POLICIES)

SUBCATCHMENT NUMBER	FUTURE % IMPERVIOUSNESS
301	43.5
302.1	47.3
302.2	43.1
302.3	43.6
303.1	30.0
303.2	55.3
304	50.3
305	37.14
306	48.2
307	37.3
308	45.5
309	40.2
310	40.3
311	42.5
312	22.3
313	55.3
314	65.0
315	52.3
316	74.8
317	75.0
318	55.6
319	46.5
320	38.2
321.1	22.2
321.2	37.3
322	8.4
323.1	31.2
323.2	37.4
324	43.0
325	58.1
326	26.2

The following landuse types and % imperviousness were considered for these areas in arriving at a representative value:

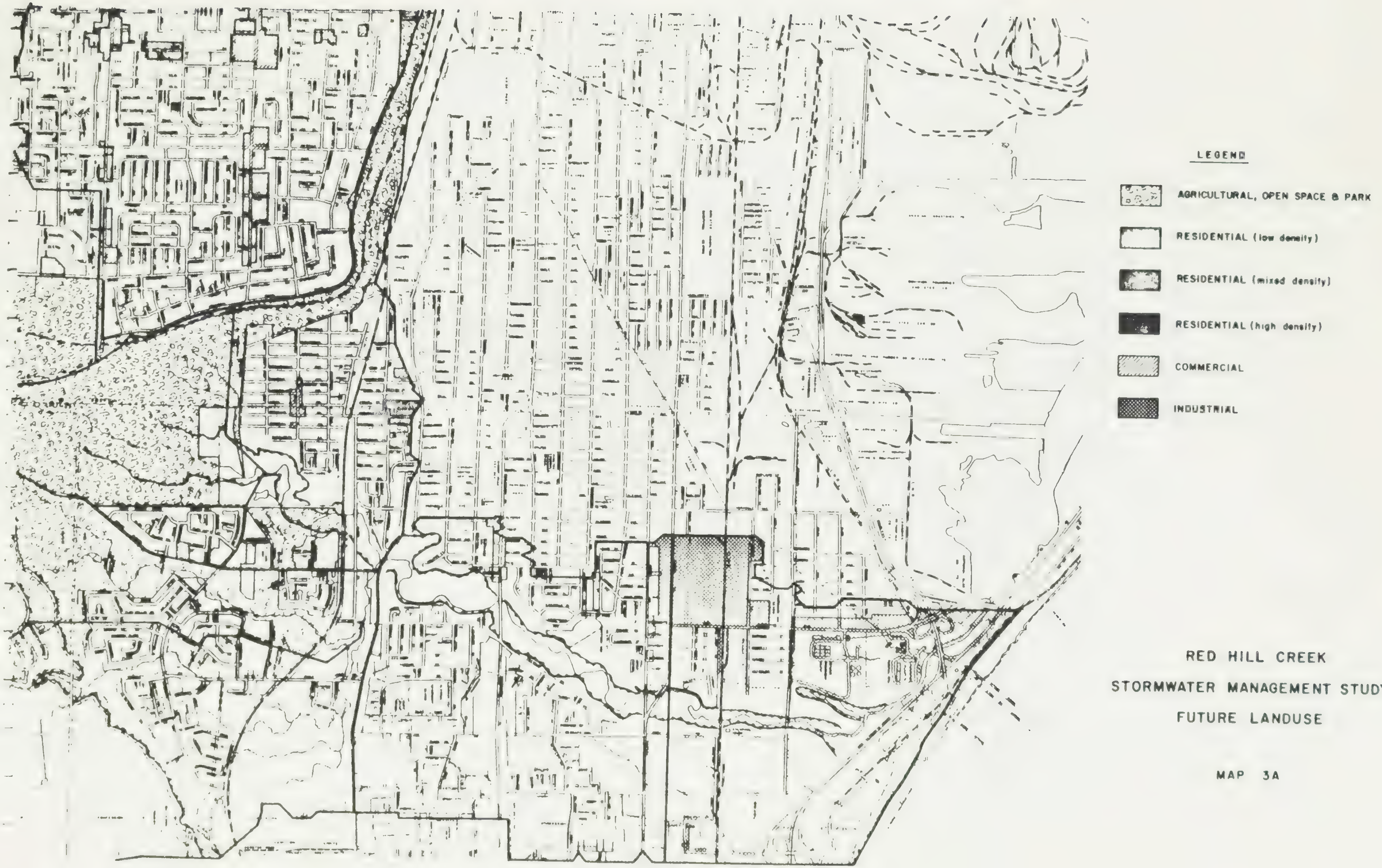
Landuse in 5 Neighbourhood Plans	% imperviousness
single and double residential	46
attached housing	55
apartments (low and medium density)	75
commercial including multicentres	90
civic and institutional	35
park and recreation + open space	5
utilities	5

The final weighted value of imperviousness thus determined for mixed residential was 45%.

The watershed map was then colour keyed according to the modelling landuse classes (see Map No's. 3a, 3b and 3c) and weighted percent imperviousness determined for each subcatchment.

It is interesting to note that the design value of imperviousness thus arrived at for subcatchment 305 which is presently almost totally developed was 37.14% which compares very closely with the actual measured value of 36.0%.

The final % impervious values thus arrived at for future conditions with present drainage policies are tabulated in Table 10.

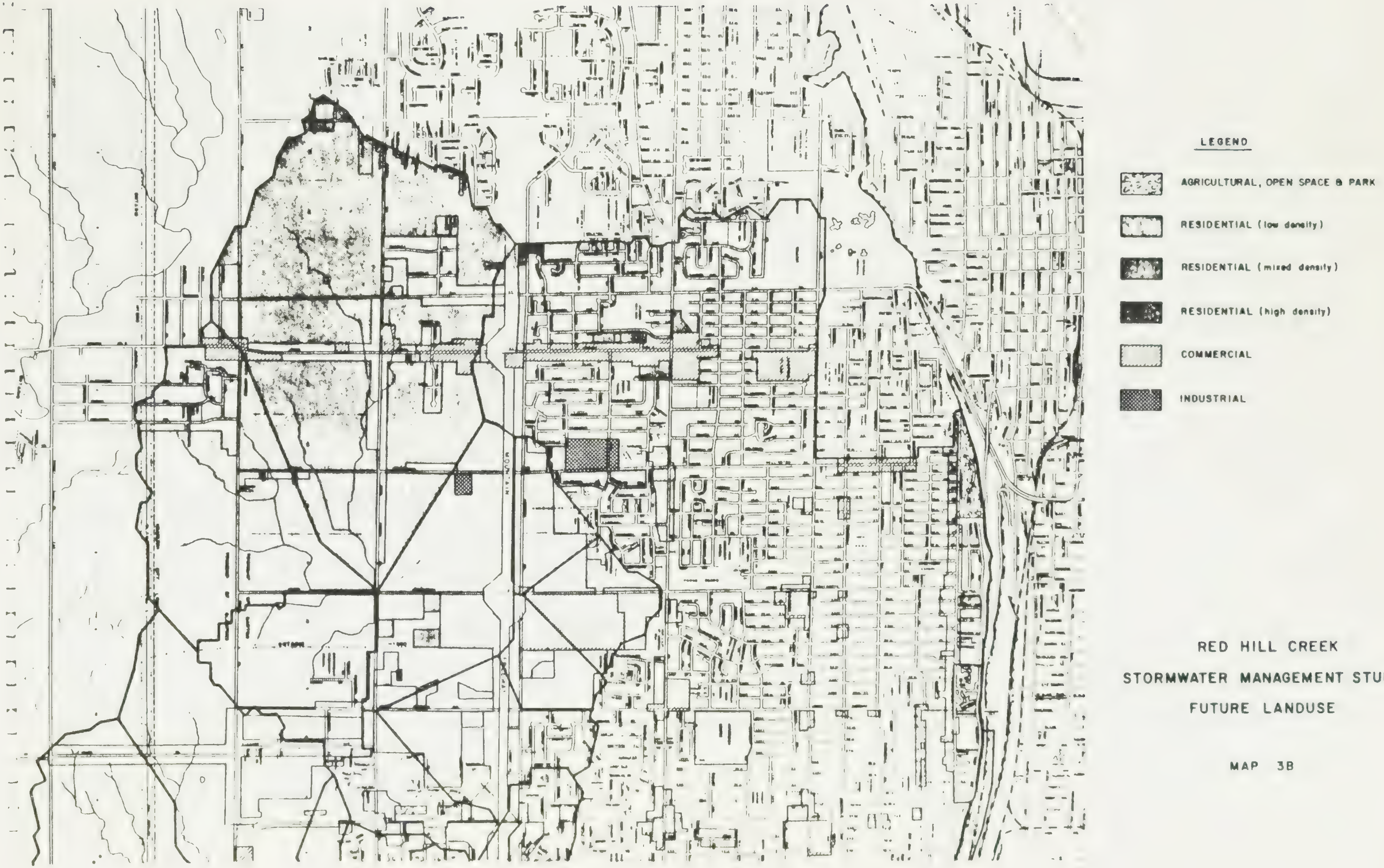


RED HILL CREEK

STORMWATER MANAGEMENT STUDY

FUTURE LANDUSE

MAP 3A

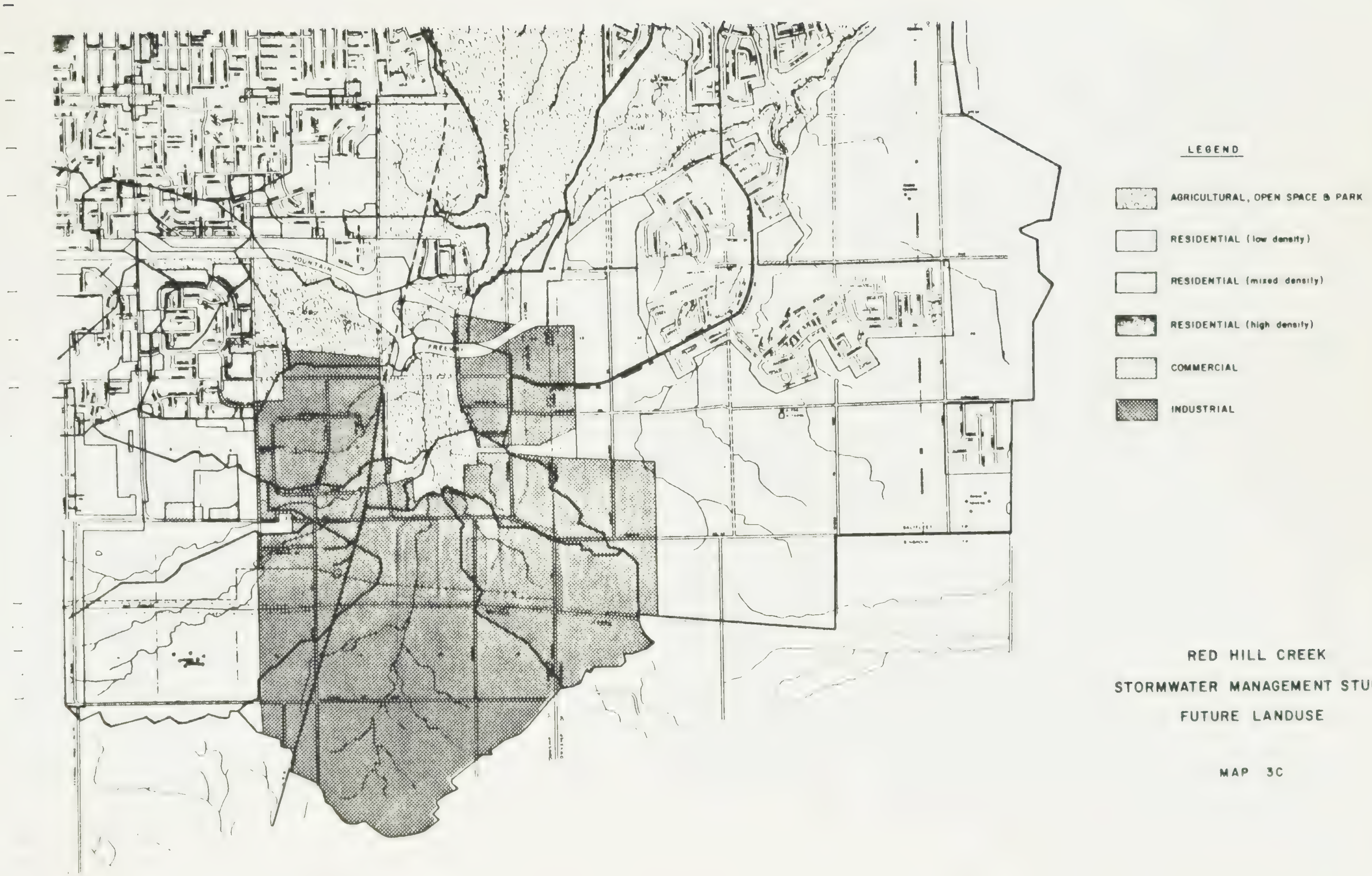


RED HILL CREEK

STORMWATER MANAGEMENT STUDY

FUTURE LANDUSE

MAP 3B



RED HILL CREEK

STORMWATER MANAGEMENT STUDY

FUTURE LANDUSE

MAP 3C

3.0 METHOD OF HYDRAULIC ANALYSIS

3.1 Techniques and Programs Used

The U.S. Army Corps of Engineers HEC-2 program was used to perform the backwater computations required for this study.

We reconstructed, set-up and checked the HEC-2 data set given us by Werner Plessl, P. Eng., of the Hamilton Region Conservation Authority. This data deck was was previously created by M. M. Dillon Limited during a flood plain mapping study of the watershed which was carried out for the Hamilton Region Conservation Authority.[8]

In order to make use of this HEC-2 data set it was necessary to know the actual location of each section on the watershed. Unfortunately the location and particularly the orientation of the cross-sections was not depicted on the original floodplain maps. This necessitated a considerable effort to re-establish as well as possible the actual location and orientation of each section. This was done according to the following considerations:

- comparison of computer printout water levels for the Regional Storm to the plotted Regional Storm floodlines
- the known length of the cross-sections and elevations at the end points
- the location of the actual channel within the section
- assumptions and knowledge that the original data set would have been carefully prepared in accordance with accepted hydraulic modelling procedures.

The recreated section locations were plotted on prints of the floodline maps and a copy was given to the Hamilton Region Conservation Authority, to facilitate their future use of the data.

Machine drawn plots of the cross-sections, produced from the actual HEC-2 data set were also produced and issued to the City of Hamilton under separate cover.

The HEC-2 program was used to develop rating curves for various stream reaches as input to the ROUTE computer program. Machine drawn plots of the rating curves thus established and used were bound and forwarded under separate cover to the City of Hamilton.

After the hydrologic modelling runs for both existing and future (existing drainage policies) landuse conditions were completed final backwater profiles were run using the actual calculated flow values at each section.

4.0 RESULTS OF WATERSHED MODELLING

Hydrologic simulations were done for the following design conditions:

- 5, 10, 25 and 100 Year design storm condition for existing landuse.
- 5, 10, 25 and 100 Year design storm conditions for future landuse.

The results of these simulations are presented in tables and in the form of plotted hydrographs. Due to the large volume of tables and hydrograph plots they have been placed in Appendices A and B respectively.

The water surface profile determined for the 100 Year Storm under future conditions was plotted on the stream profiles which were presented as Drawing No.'s. 1, 2 and 3 in Section 1.2. The degree of backup and its extent behind the various embankments may be clearly seen on these drawings.

4.1 Presentation of Results

The results of the hydrologic simulations are presented grouped together as follows to facilitate comparisons and evaluation of problem areas.

4.1.1 Table Set No. 1: Comparison of Existing and Future Peak Flows (no runoff controls)

This set of tables (2 pages) is found in Appendix A and contains flow comparisons at all nodal locations (Maps 2a, b, c) for all design storms.

Table 11 which follows shows the effect of proposed development on peak flood flows at selected locations when no runoff controls are in effect.

4.1.2 Table Set No. 2: Analysis of Routing Reaches for Maximim Velocities and Peak Flow Reductions

This set of tables is also found in Appendix A and is presented for two conditions:

- existing condition (first 3 pages)
- future condition (last 2 pages)

TABLE NO. 11: EFFECT OF PROPOSED DEVELOPMENT ON PEAK FLOOD FLOWS AT SELECTED LOCATIONS (NO RUNOFF CONTROLS)

LOCATION AND COMMENTS	% PEAK FLOW INCREASE WITH DEVELOPMENT			
	5 YEAR	10 YEAR	25 YEAR	100 YEAR
S. BRANCH ABOVE ESCARPMENT (NODE 11) - MAJOR LANDUSE SHIFT FROM RURAL TO INDUSTRIAL	601	443	418	283
W. BRANCH ABOVE ESCARPMENT (NODE 8.1) - MAJOR LANDUSE SHIFT FROM RURAL TO MIXED RESIDENTIAL	249	156	146	79
ALBION FALLS (NODE 14)	290	198	184	112
MAIN STREAM AT TH&B (REACH 709 OUTFLOW)	52	25	24	12
SMALLER EASTER TRIB. (REACH 713 OUTFLOW) - CONSIDERABLE SHIFT OF RURAL TO MIXED RESIDENTIAL	43	23	18	6
LARGER EASTERN TRIB. (REACH 714 OUTFLOW) - MAJOR LANDUSE SHIFT FROM RURAL TO MIXED RESIDENTIAL	102	51	42	19
TOTAL EASTERN TRIB. (NODE 21)	85	44	36	16
TOTAL WATERSHED JUST DOWNSTREAM OF LAST OF MAJOR TRIBUTARIES (NODE 22)	59	29	26	12
TOTAL WATERSHED AT MOUTH (NODE 24)	47	28	23	15

In this table set the effect of the storage in each routing reach identified in Map Set 2 (a, b, c) is presented along with the maximum velocity in the reach for the noted conditions of landuse and design storm. The reach type (concrete box sewer, normal sewer, stream, storage facility) is also noted. Where the reach is a stream (700 series) the section number at which the maximum velocity is found for each storm and landuse condition is also identified.

For the existing conditions presentation, the existence of major flow (overflow from minor system) in sewers (500 series mainly) is identified along with the associated maximum velocities and peak flow reductions. For these cases the overall reach (major + minor) is also shown. The major system flow is characterized by shallower depth and wider widths of flow (e.g. along a roadway between the curbs instead of in a sewer) resulting in lower velocities and associated greater storage and peak flow reduction. From the Red Hill Creek simulation results, major flows where they occurred were roughly 1/3 to 1/2 the velocity of accompanying minor system flows and exhibited peak flow reductions due to storage roughly 3 times or more as great as found in the minor system. It must be remembered however that during conditions of overflow minor system peak flow reductions are somewhat negligible. They only occur at all due to the fact that for a short time inflows in excess of pipe capacity will occur before the pipes actually fill and overflow to the major flow system.

4.1.3 Table Set No. 3: Analysis of Stream Reaches for Storage and Embankment Overtopping

This set of tables, found in Appendix A, presents detailed results and key points regarding the performance of the stream valley reaches for the following conditions: (2 pages each)

- 5 Year Storm Existing Conditions
- 5 Year Storm Future Conditions (no runoof controls)
- 10 Year Storm Existing Conditions
- 10 Year Storm Future Conditions (no runoff controls)

- 25 Year Storm Existing Conditions
- 25 Year Future Conditions (no runoff controls)
- 100 Year Storm Existing Conditions
- 100 Year Storm Future Conditions (no runoff controls)

In these tables for each combination of reach (see Map 2a, b, c), storm and development the following are presented:

- peak inflow
- peak outflow
- % reduction in peak flow due to allowance for storage in the reach through routing calculations taking into account the backwater effect of structures
- the amount of storage used for this combination of storm and landuse
- the maximum amount of storage in the reach
- the time lag between the time the peak inflow to and peak outflow from the reach occurred. This time is presented to the nearest 5 minutes since this was the time step used in the calculations. A lag of less than 5 minutes would show up as zero.

For up to two major structures within a reach the following information is also presented:

- the name of the structure embankment (e.g. TH&B railway)
- the height of the embankment, expressed as the elevation difference between the stream invert and the lowest point on the embankment crest where overflow would first begin.
- the section number corresponding to the structure in the HEC-2 data set is also given in brackets.
- the freeboard existing for each condition. This is the distance between the water surface and the low point on the embankment crest and represents how much more the water level would have to rise before the embankment was overtopped. A zero or negative value for this item indicates that the embankment would be overtopped for that combination of landuse and design storm.

4.1.4 <u>Table Set No. 4: Location and Conditions of Erosive Velocities</u>

In this set of tables, contained in Appendix A and comprising 9 pages the cross sections within each stream reach are listed and may be correlated to the cross section plots, rating curve plots and the HEC-2 data set. For each combination of storm and landuse (future is with present drainage policies) the maximum velocities for each cross section are listed oppostie the section number, if the maximum velocity within the section exceeded 5 feet per second. This is the threshold velocity at which erosion of a grass lined channel might begin, although in some cases grass lined channels may be designed for velocities up to 6 feet/second. If the channel is lined with rock or gabion baskets then it can safely convey flow at a somewhat higher velocity.

4.1.5 <u>Plotted Hydrographs</u> (found in Appendix B)

<u>Hydrograph Set No. 1: Existing vs Future (no controls) Runoff Hydrographs at Selected Locations</u>

This set of 24 plotted hydrograph sheets depicts vividly the impact of future development on design storm hydrographs at selected locations. Hydrograph plots are presented for the 5 Year, 10 Year, 25 Year and 100 Year Storms at the following nodal locations: (see Map 2a, b, c)

- node 8.1 - the outlet of the 18 ft. by 15 ft. trunk storm sewer running parallel to Limeridge Road. This outlet is a short distance upstream of the CNR tracks at the Ottawa Street dump.
- node 11 - the main stream after picking up most of the planned Glanbrook Industrial park.
- node 14 - the main stream at Albion Falls
- node 21 - the confluence of the two main branches of the eastern tributary
- node 22 - the confluence of the eastern tributary and the main stream
- node 24 - the mouth of the creek at Hamilton Harbour (Windermere Basin)

Hydrograph Set No. 2: Importance of Various Branches at Various Junctions for Various Conditions

This set of hydrograph plots is intended to depict the relative contributions of the creek branches at particular junctions for all storms, under both existing and future conditions (no runoff controls.

These 24 sheets of plots may be found in Appendix B and cover the following junction points as follows:

- node 12 - the junction of the western tributary and main stream. The total flows at this point are plotted against the contribution from reach 701 (the western portion of largerly residential)
- node 20 - the junction of the main stream at the Greenhill Storage Facility. The total flow hydrographs at this location are plotted against the contributions from reach 810 (Fennell Avenue trunk after Greenhill Storage Facility) and reach 708 (the main stream)
- node 22 - the junction of the main stream and the eastern tributary. The total flow hydrographs at this point are plotted against the contribution from the main stream (reach 709), the contribution from each of the two branches of the eastern tributary (reaches 713 and 714).

Hydrograph Set No. 3: Inflow and Outflow Hydrographs for Stream Reaches with Significant Storage

In this set of 40 sheets of hydrograph plots are depicted the inflow and outflow hydrographs for those reaches whose storage has the greatest impact on peak flows. This was done for the following reaches: (see Map 2 a, b, c)

- reach 709 - main stream behind TH&B embankment
- reach 711 - main stream between King Street and Barton Street

- reach 712 - main stream from Barton Street to the mouth at Hamilton Harbour
- reach 713 - the smaller of the two branches of the eastern tributary with storage behind the TH&B embankment
- reach 715 - the larger of the two branches of the eastern tributary with storage behind the TH&B embankment.

4.2 Effect of Selected Stormwater Management Controls on Design Flows

4.2.1 Description of Stormwater Management Control

After discussions with the technical co-ordinating committee for this project about the results of modelling of future landuse conditions it was decided to only simulate the effects of agreed upon stormwater management techniques applied to the Glanbrook Industrial Area. For this area it was decided to test the effectiveness of requiring 2.54 cm (1 inch) of storage for all impervious areas in industrial landuses. The manner in which this amount of storage would be provided could vary from site to site and could involve such measures as:

- roof top storage (only get credit for 2.54 cm)
- parking lot storage
- detention ponds

In the SUBHYD program, depression storage is modelled with the use of Linsley's[1] exponential depression storage equation. With this equation, there is some immediate runoff but no significant amount occurs until all depressions are filled. For this reason, simply specifying a depression storage of 2.54 cm for impervious areas in SUBHYD, provides a reasonable modelling simulation of the desired control.

This 2.54 cm of impervious depression storage was specified for the following subcatchments: (see Map Set. No. 2)

- 313
- 314
- 315
- 316
- 317
- 318
- 319

The watershed was then resimulated with the modified future conditions for the following design storms:

- 5 Year
- 25 Year
- 100 Year

4.2.2 Effect of Selected Industrial Stormwater Management Control

The effectiveness of requiring 2.54 cm of storage for all impervious areas in the Glanbrook industrial park is illustrated in Table No.'s. 12 and 13. Table No. 12 presents the results at a subcatchment level while Table No. 13 presents the results at selected points throughout the watershed. It can be seen from these tables that this stormwater management technique would greatly reduce the impact of the planned development on the watershed, although runoff from the area would still be considerably greater than under existing conditions. A greater degree of control could be attained by providing a larger amount of storage.

The amount of storage represented by 2.54 cm over all impervious surfaces in the Glanbrook industrial park is 136,000 m^3.

Alternatively, a flood control reservoir could be built at reach 704, upstream of Albion Falls. Such a reservoir would exert some control over almost all new development on the main stream upstream of Albion Falls and has previously been proposed.

Varying amounts of storage could be provided at this site depending on the depth of ponding as shown below:

POSSIBLE RESERVOIR STORAGE AT REACH 704

WATER LEVEL (feet)	STORAGE		SURFACE AREA		COMMENTS
	1000 m^3	Ac-Ft	Hectares	Acres	
600	145	117.9	10.7	26.4	- 0.5 m freeboard at Stonechurch Road - Ponding extended to about 150 m upstream of Stonechurch Road
605	372	302	19.3	47.6	- would have to raise Stonechurch Road by 1 metre at creek - ponding extended to about 460 m upstream of Stonechurch Road
610	729	592	26.5	65.6	- close Stonechurch Road between CNR tracks and Albion Road and block underpass under CNR - ponding extended to about 760 m upstream of Stonechurch Road (275 m downstream of Rymal Road).

TABLE NO. 12

EFFECT OF 2.54 cm IMPERVIOUS AREA STORAGE STORMWATER MANAGEMENT CONTROL FOR GLANBROOK INDUSTRIAL PARK AT A SUBCATCHMENT LEVEL

SUBCATCHMENT NO.	PEAK FLOWS								
	5 YEAR STORM			25 YEAR STORM			100 YEAR STORM		
	WITHOUT SWM	WITH SWM	% REDUCTION	WITHOUT SWM	WITH SWM	% REDUCTION	WITHOUT SWM	WITH SWM	% REDUCTION
313	27.5	11.4	58.5	42.9	25.5	40.6	58.1	44.0	24.3
314	8.75	3.57	59.2	13.6	7.97	41.4	18.2	13.7	24.7
315	40.1	15.5	61.3	62.4	35.8	42.6	84.1	62.8	25.3
316	78.5	29.9	61.9	120.3	67.7	43.7	159.1	117.1	26.4
317	31.9	12.5	60.8	49.0	28.2	42.4	65.2	48.5	25.6
318	14.0	5.83	58.4	21.9	13.0	40.6	29.8	22.5	24.5
319	10.8	4.76	55.9	15.1	10.7	29.1	19.0	16.1	15.3

TABLE NO. 13

EFFECT OF 2.54 cm IMPERVIOUS AREA STORAGE STORMWATER MANAGEMENT CONTROL FOR GLANBROOK INDUSTRIAL PARK AT SELECTED LOCATIONS THROUGHOUT THE WATERSHED

NODE NO.	PEAK FLOWS (m^3/s)								
	5 YEAR STORM			25 YEAR STORM			100 YEAR STORM		
	WITHOUT SWM	WITH SWM	% REDUCTION	WITHOUT SWM	WITH SWM	% REDUCTION	WITHOUT SWM	WITH SWM	% REDUCTION
9	71.8	47.2	34	112.4	85.7	24	152	131.2	14
10	110	42.4	61	169	95.9	43	224	165.7	26
11	115	63.6	45	168	114	32	224	181.0	19
13	187	149	20	273	241	12	352	318	10
14	186	148	20	274	237	14	354	315.8	11

5.0 CONCLUSIONS

After reviewing the results of the hydrologic simulation modelling presented in Chapter 4 and Appendices A and B, the following conclusions may be drawn:

1. Fully developing the presently undeveloped areas of the Red Hill Creek upstream from Albion Falls will dramatically increase peak flow rates at Albion Falls by a factor of 2.8 during a 25 Year Storm.

2. The impact of future development on major flood flows will not be nearly as significant in the lower reaches of the creek because it will be largely "damped out" by ponding behind the TH&B embankment. The 25 Year Storm peak flow at the confluence of the main stream and eastern tributary, a short distance downstream from the TH&B embankment will only increase by a factor of 1.26. By the mouth of the creek this factor would be further reduced to 1.23.

3. The most intense development is expected to take place in the Glanbrook Industrial Park. The impact of this development could be significantly reduced by the provision of on-site temporary storage equivalent to 2.54 cm (see pages 22 and 23) over the entire impervious area. This would reduce the future 25 Year Storm peak flow by 30% to 40% from this area and the total 25 Year Storm peak flow at Albion Falls would be 14% less than otherwise.

4. The TH&B embankment crossing the main stream and both major branches of the eastern tributary acts similar to a flood control dam, which, if stable during such an event, would back water up greatly reducing peak flows.

5. Although the TH&B embankment across the main stream was not overtopped during any of the simulations, its failure during a 100 Year Future condition storm event is quite possible. During this simulation water was ponded to a depth of 13.4 m behind the embankment, which represents 82% of the embankment's height, and is higher than the roofs of numerous homes located a short distance downstream. If the embankment were to fail during such an event, the consequences would likely be catastrophic. Just downstream from this embankment the creek has a 90^{o} bend and during such a failure, flood waters

would overtop the bank and likely wash away many of the homes located on Sinclair and Elaine Courts and flood numerous homes along Lawrence Road near King Street. Failure of the TH&B embankment during such an event would also likely lead to subsequent failure of the downstream crossings and considerable flooding at the sewage and water treatment plants located at the mouth of the creek.

The embankment would not have been designed to act as a dam but could be reinforced to be able to safely withstand such extreme ponding conditions. The stabilizing of this embankment as necessary would be very worthwhile since it acts so effectively as a natural flood control structure.

6. Numerous locations and conditions of potentially erosive velocities were identified. The consequences of such velocities cannot be evaluated however without a comprehensive survey of the stream channel to establish permissible velocities along its length and to identify the extent and location of existing erosion protection works.

7. The capacity of the various structures along the stream reaches modelled is adequate for existing conditions since during the 25 Year Storm condition only Hixon Road and the old Barton Street crossing would be overtopped. The Hixon Road structure is only used at present as a footbridge and the Barton Street crossing has been recently rebuilt just downstream from the old structure.

   Under future 25 Year Storm conditions the following structures would be overtopped:

   - C.N.R. culvert (west of Dartnall Road)
   - Stonechurch Road
   - Quigley Side Road

8. The detailed watershed modelling carried out for this Study has demonstrated the following:

   - due to the shape of the watershed (narrow in the lower reaches and flairing out in the upper reaches), and the low slopes and large storage volumes in the

lower watershed, the peak flows in the watershed are greatest in the area of confluence of the major tributaries near the Greenhill Storage facility. Proceeding from this point downstream, the attenuative effects of valley storage more than compensate for the slightly increasing watershed area.

- The large embankments in the lower watershed have a very significant impact on peak flood flows.

Floodplain mapping for the watershed which was done some time ago, using techniques common at the time, considered the entire watershed as simply a single subcatchment, and did not consider these effects. Peak flows were estimated at the mouth of the basin and simply related to drainage area in other parts of the watershed. If the floodplain mapping were redone, with the level of detail considered in this study, significantly different results would likely be obtained. Such work should not at first assume that the embankments will fail as is commonly done. Rather it should determine the impact of the embankments on Regional Storm flood flows and levels and then establish what if anything, would be required to make the embankments stable. Then the cost effectiveness of stabilizing the embankments if and as necessary could be established versus the cost of alternative culvert replacements through the embankments and downstream channel improvements.

6.0 RECOMMENDATIONS

Based upon the results of this study, the following recommendations are submitted:

1. Stormwater management techniques and principles should be implemented as follows:

   (a) provision should be made in drainage design for both minor drainage system and a major or overflow drainage system for all new development. The minor and major systems should be designed to the 5 and 100 Year Storm level respectively.

   (b) roof drains should not be connected to sewers in the residential areas. They should discharge onto concrete splash pads located at ground level and lot grading should be such that roof drain flow will drain away from the building so that infiltration may occur.

   (c) detention storage equal to 2.54 cm for all impervious surfaces should be provided in new industrial development.

2. A comprehensive survey of the storm channels should be carried out to establish maximum permissible velocities at all locations. This work should be referenced to the existing floodplain mapping of the watershed. The results of this survey, when correlated with the results presented in Table Set. No. 4 in Appendix A will allow a determination of the extent and severity of both existing and potential future erosion problems.

3. Stability analyses should be carried out for the major embankments which pond water and tend to act as natural flood control reservoirs, effectively helping to control both existing and future flooding. The TH&B embankment which crosses 3 branches of the creek below the escarpment is most important from this point of view. Emphasis should be on taking what steps are necessary to ascertain that these embankments remain stable, rather than on increasing their capacity.

4. The C.N.R. (west of Dartnall Road), Stonechurch Road and Quigley Side Road structures should be rebuilt with increased capacity to handle future flows. Rather than size these structures to pass all conceivable flows, provision shoud be made, where practical, to allow the structure to be safely overtopped during a major flood event.

7.0 LIST OF REFERENCES

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(11) Delaware University, "Water Resources Protection Measures in Land Development, A Handbook", Prepared for Office of Water Resources Research, April, 1974.

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APPENDIX A:

STUDY RESULTS GROUPED INTO VARIOUS TABLES

Table Set No. 1:

Comparison of Existing and Future Peak Flows
(no runoff controls)

TABLE SET NO. 1

RED HILL CREEK: COMPARISON OF EXISTING AND FUTURE PEAK FLOWS

(NO RUNOFF CONTROLS)

NODE NO.	5 YEAR FLOWS (CMS)		10 YEAR FLOWS (CMS)		25 YEAR FLOWS (CMS)		100 YEAR FLOWS (CMS)	
	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
1	11.32	87.67	17.19	110.4	22.54	138.8	38.24	190.1
2	3.14	22.00	4.75	27.61	6.09	35.36	10.23	49.38
3	16.46	104.4	26.05	106.7	33.89	160.3	58.62	213.0
4	11.45	17.57	14.34	21.87	18.29	27.83	24.61	38.24
5	21.87	111.0	33.13	114.2	42.71	162.1	72.19	207.8
6	27.68	110.3	43.10	121.4	54.60	162.7	91.42	197.7
7	6.11	10.23	7.99	12.75	10.25	16.25	14.92	22.44
8	32.13	114.2	49.74	129.5	62.81	155.9	104.6	197.1
8.1	33.18	115.7	51.79	132.8	65.17	160.4	109.2	195.2
9	8.10	71.76	12.96	89.10	16.74	112.4	29.42	152.3
9.1	8.84	52.05	14.24	63.44	18.42	77.08	32.20	103.7
10	7.00	110.4	11.27	134.8	14.41	169.3	25.38	224.3
11	16.44	115.2	25.67	139.3	32.50	168.4	58.34	223.5

TABLE SET NO. 1

RED HILL CREEK: COMPARISON OF EXISTING AND FUTURE PEAK FLOWS

(NO RUNOFF CONTROLS)

NODE NO.	5 YEAR FLOWS (CMS)		10 YEAR FLOWS (CMS)		25 YEAR FLOWS (CMS)		100 YEAR FLOWS (CMS)	
	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
12	51.24	210.1	79.82	255.1	100.6	305.1	171.9	389.5
13	47.85	187.4	76.62	228.6	95.75	272.9	165.9	352.1
14	47.75	186.2	76.96	229.0	96.41	273.5	166.4	353.5
15	12.52	25.79	16.54	32.46	21.11	40.75	30.58	54.49
16	50.79	187.2	84.91	237.5	106.5	284.5	186.7	376.6
18	121.6	122.3	145.3	146.3	179.4	180.5	257.6	259.5
19	112.9	113.1	138.6	139.2	169.8	170.0	241.6	242.3
20	132.6	234.9	178.4	295.1	223.6	359.1	336.2	525.8
21	19.61	36.33	29.39	42.42	33.03	44.99	45.04	52.26
22	83.44	132.8	122.0	157.3	133.4	168.4	174.1	195.4
23	64.88	91.14	46.94	110.9	97.60	117.0	129.0	147.1
24	56.35	82.86	83.44	106.4	91.22	111.8	124.3	142.9
25	10.48	30.01	15.08	38.97	19.11	48.92	29.87	86.57

Table Set No. 2:

Analysis of Routing Reaches for Maximum Velocities and Peak Flow Reductions

- existing conditions
- future conditions

TABLE SET NO. 2

ANALYSIS OF REACHES FOR MAXIMUM VELOCITIES AND PEAK FLOW REDUCTION

CONDITION: EXISTING

REACH NO.	TYPE	5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION
501.0	CONC. BOX	2.45	6.11	2.83	3.19	3.06	3.32	3.57	1.87
502.0	CONC. BOX	2.43	4.73	2.72	2.86	2.88	3.54	3.25	3.31
503.0	CONC. BOX	2.85	2.18	3.30	2.03	3.57	1.42	4.15	0.96
504.0 (MAJOR)	CONC. BOX	* 2.89 0.50	36.5 81.3 } 39.2	* 2.94 0.73	39.1 75.2 } 45.2	* 2.96 0.85	30.36 69.84 } 48.3	* 3.00 1.25	24.8 65.8 } 47.8
505.0	CONC. BOX	3.07	6.45	3.51	4.29	3.77	4.24	4.34	3.46
506.0	CONC. BOX	3.35	2.95	3.81	2.62	4.07	2.00	4.62	1.29
507.0 (MAJOR)	CONC. BOX	* 3.04 0.79	10.1 47.2 } 13.9	* 3.19 1.10	11.7 36.3 } 18.7	* 3.25 1.33	8.37 30.97 } 18.4	* 3.23 1.59	6.4 26.1 } 18.7
510.0	CONC. BOX	3.41	2.08	3.90	1.30	4.17	1.84	4.79	1.29
701.0	STREAM	2.64	4.66	2.87	3.22	3.03	3.76	3.41	3.10
601.0	SEWER	2.64	2.14	3.02	0.94	3.22	0.50	3.64	0.43
601.1 (MAJOR)	STREAM	2.53 : 7003.0	5.37	* 2.93 : 7003.0	0.0 24.96 } 9.5	* 3.14 : 7003.0	15.63 21.06 } 10.9	* 3.42 : 7002.0	0.0 11.7 } 8.51

* MINOR SYSTEM FLOW RECORDED, MAJOR SYSTEM FLOW ALSO PRESENT.

TABLE SET NO. 2

ANALYSIS OF REACHES FOR MAXIMUM VELOCITIES AND PEAK FLOW REDUCTION

CONDITION: EXISTING

REACH NO.	TYPE	5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION
702.0	STREAM	2.46 : 73.0	2.25	2.77 : 73.0	0.89	2.96 : 73.0	1.52	3.01 : 68.0	1.74
703.0	STREAM	1.62 : 65.0	4.94	1.87 : 65.0	5.03	1.82 : 65.0	2.38	2.27 : 65.0	5.78
704.0	STREAM	2.74 : 59.0	6.63	3.26 : 59.0	4.01	3.63 : 59.0	4.79	4.16 : 59.0	3.47
705.0	STREAM	3.27 : 56.8	1.31	3.84 : 56.8	0.75	4.20 : 56.8	0.39	5.05 : 56.8	0.82
706.0	STREAM	3.68 : 53.0	0.97	4.18 : 55.0	0.29	4.46 : 55.0	1.09	5.27 : 55.0	0.34
707.0	STREAM	2.78 : 2002.0	30.84	3.05 : 2002.0	29.46	3.29 : 2005.0	29.96	3.78 : 2005.0	25.71
708.0	STREAM	3.69 : 49.0	30.01	4.19 : 49.0	7.87	4.46 : 49.0	56.0	4.77 : 49.0	27.10
508.1	CONC. BOX (MAJOR)	* 6.42 2.49	24.2 64.3 } 41.8	* 6.42 2.92	19.5 58.6 } 42.2	* 6.42 2.98	15.94 56.11 } 43.5	* 6.42 3.84	5.1 51.8 } 42.5
508.0	CONC. BOX (MAJOR)	* 6.42 1.83	0.0 65.9 } 17.8	* 6.42 2.41	0.07 51.8 } 21.6	* 6.42 2.78	24.14 42.15 } 22.5	* 6.42 3.33	0.0 32.0 } 21.5
509.0	CONC. BOX (MAJOR)	* 7.94 2.95	0.0 21.4 } 7.1	* 7.94 3.43	0.0 10.4 } 4.6	* 7.94 3.78	15.73 3.47 } 5.39	* 7.94 4.37	0.0 9.1 } 6.2
810.0	STORAGE FACILITY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* MINOR SYSTEM FLOW RECORDED, MAJOR SYSTEM FLOW ALSO PRESENT.

TABLE SET NO. 2

ANALYSIS OF REACHES FOR MAXIMUM VELOCITIES AND PEAK FLOW REDUCTION

CONDITION: EXISTING

REACH NO.	TYPE	5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION
709.0	STREAM	3.45 : 40.0	49.66	3.57 : 41.0	46.30	3.17 : 42.0	53.46	2.39 : 37.0	60.39
713.0	STREAM	2.46 : 1012.0	47.74	2.65 : 1012.0	52.66	2.75 : 1012.0	58.68	2.90 : 1012.0	65.29
715.0	STREAM	3.03 : 1115.0	26.29	3.51 : 1115.0	27.76	3.53 : 1118.0	37.52	3.94 : 1118.0	45.34
714.0	STREAM	3.19 : 1110.0	3.60	3.56 : 1110.0	3.76	3.76 : 1110.0	1.83	4.02 : 1104.0	4.51
710.0	STREAM	1.35 : 1002.0	12.58	0.52 : 1000.0	6.48	0.52 : 1000.0	5.49	0.47 : 1000.0	4.58
711.0	STREAM	3.43 : 30.0	22.79	4.13 : 23.0	26.83	3.59 : 31.0	27.1	4.16 : 31.0	26.08
712.0	STREAM	2.92 : 2.0	13.14	3.31 : 2.0	7.71	3.41 : 2.0	6.53	3.76 : 2.0	3.66
712.1	STREAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* MINOR SYSTEM FLOW RECORDED, MAJOR SYSTEM FLOW ALSO PRESENT.

TABLE SET NO. 2

ANALYSIS OF REACHES FOR MAXIMUM VELOCITIES AND PEAK FLOW REDUCTION

CONDITION: FUTURE

REACH NO.	TYPE	5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION
501.0	CONC. BOX	4.11	19.25	4.16	41.37	4.45	26.77	4.47	29.67
502.0	CONC. BOX	2.90	36.89	3.30	38.13	3.28	42.65	3.28	43.72
503.0	CONC. BOX	4.69	5.48	4.70	7.28	5.04	10.62	5.04	15.03
504.0	CONC. BOX	2.64	43.28	3.00	44.57	2.98	46.21	2.99	45.56
505.0	CONC. BOX	4.74	12.58	4.79	7.90	5.04	13.08	5.04	17.39
506.0	CONC. BOX	4.78	3.12	4.90	1.31	5.04	10.99	5.04	7.39
507.0	CONC. BOX	2.86	17.95	3.25	18.41	3.20	18.50	3.25	17.79
510.0	CONC. BOX	4.90	1.14	5.06	0.44	5.28	0.20	5.48	3.66
701.0	STREAM	3.41	7.34	3.50	5.72	3.60	4.92	3.70	1.66
601.0	SEWER	3.24	32.69	3.68	33.49	3.67	35.38	3.67	35.43
601.1	STREAM	5.15 : 7001.0	18.83	-.34 : 7001.0	16.65	4.57 : 7001.0	18.14	4.91 : 7001.0	17.21
702.0	STREAM	3.33 : 68.0	33.78	3.53 : 68.0	35.62	3.70 : 68.0	38.34	4.02 : 68.0	40.09
703.0	STREAM	2.85 : 65.0	10.46	3.05 : 65.0	10.77	3.24 : 65.0	11.79	3.56 : 65.0	11.97
704.0	STREAM	4.27 : 59.0	10.81	4.41 : 59.0	10.39	4.56 : 59.0	10.55	4.85 : 59.0	9.61
705.0	STREAM	5.25 : 56.8	1.05	5.56 : 56.8	0.31	5.92 : 56.8	0.26	6.33 : 56.8	0.16

TABLE SET NO. 2

ANALYSIS OF REACHES FOR MAXIMUM VELOCITIES AND PEAK FLOW REDUCTION

CONDITION: FUTURE

REACH NO.	TYPE	5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION	MAX. VEL.: SECT. NO. (M/S)	% PEAK REDUCTION
706.0	STREAM	5.39 : 55.0	3.25	5.71 : 55.0	2.01	5.89 : 55.0	1.91	6.42 : 55.0	1.49
707.0	STREAM	3.40 : 2005.0	36.50	3.66 : 2005.0	36.72	3.91 : 2005.0	38.12	4.36 : 2005.0	34.44
708.0	STREAM	4.88 : 49.0	21.88	5.14 : 49.0	22.95	5.44 : 50.0	18.55	5.85 : 50.0	12.22
508.1	CONC. BOX	6.42	42.04	6.42	42.53	6.42	43.77	6.42	42.77
508.0	CONC. BOX	6.42	18.24	6.42	21.74	6.42	22.63	6.42	21.61
509.0	CONC. BOX	7.94	7.57	7.94	4.83	7.94	5.79	7.94	6.62
810.0	STORAGE FACILITY	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
709.0	STREAM	3.66 : 42.0	56.88	2.97 : 42.0	59.37	2.33 : 37.0	64.21	2.53 : 37.0	71.70
713.0	STREAM	2.75 : 1012.0	73.81	2.84 : 1012.0	77.42	2.89 : 1012.0	11.04	3.36 : 1012.0	85.31
715.0	STREAM	3.74 : 1118.0	71.36	3.92 : 1118.0	74.05	3.99 : 1118.0	72.59	4.16 : 1118.0	80.86
714.0	STREAM	3.75 : 1104.0	7.40	3.96 : 1104.0	8.02	4.02 : 1104.0	8.17	3.46 : 1110.0	10.42
710.0	STREAM	1.74 : 32.0	10.72	1.81 : 32.0	7.66	1.88 : 32.0	6.78	1.78 : 32.0	3.86
711.0	STREAM	3.46 : 30.0	31.69	3.86 : 31.0	29.88	4.06 : 31.0	30.68	3.57 : 31.0	24.94
712.0	STREAM	3.31 : 2.0	9.54	3.58 : 2.0	4.51	3.63 : 2.0	4.69	3.92 : 2.0	3.10
712.1	STREAM	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

- 5 YEAR STORM EXISTING CONDITIONS
- 5 YEAR STORM FUTURE CONDITIONS
- 10 YEAR STORM EXISTING CONDITIONS
- 10 YEAR STORM FUTURE CONDITIONS
- 25 YEAR STORM EXISTING CONDITIONS
- 25 YEAR STORM FUTURE CONDITIONS
- 100YEAR STORM EXISTING CONDITIONS
- 100 YEAR STORM FUTURE CONDITIONS

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 5 YEAR   CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION: 1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	8.84	8.37	5.37	2.86	-	0.167	8.32 (981.5)	5.3 C.N.R.	-	-
701.0	33.18	31.63	4.66	13.32	37.37	0.167	-	-	-	-
702.0	7.00	6.84	2.25	1.54	10.49	0.167	-	-	-	-
703.0	16.44	15.63	4.94	4.39	32.01	0.167	2.59 (909.5)	1.45 Stone Church Rd.	-	-
704.0	51.24	47.85	6.63	38.68	109.9	0.167	-	-	-	-
705.0	47.85	47.22	1.31	7.87	26.80	0.0	-	-	-	-
706.0	47.75	47.28	0.97	6.51	29.10	0.083	-	-	-	-
707.0	12.52	8.66	30.84	1.74	8.56	0.083	7.80 (950.5)	6.57 Mt. Brow Blvd.	-	-
708.0	50.79	45.31	10.80	30.01	511.9	0.167	-	-	-	-
709.0	132.6	66.76	49.66	114.7	1599.0	0.750	2.74 (906.5)	0.45 Hixon Rd.	16.25 (907.5)	11.97 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 5 YEAR CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION DESCRIPTION			
							1ST STRUCTURE		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	19.61	17.15	12.58	16.60	113.7	0.500	6.12 (920.5)	4.08 Albion Rd.	- -	- -
711.0	83.44	64.43	22.79	193.1	1998.0	0.917	9.69 (904.5)	6.37 Queenston Rd.	2.80 (903.5)	-0.56 Barton St.
							4.11 (905.5)	1.59 King St.		
712.0	64.88	56.35	13.14	166.7	1166.0	0.667	2.87 (901.5)	1.22 Burlington St.	10.21 (902.5)	7.12 CN
							3.84 (900.5)	2.89 Woodward Ave.		
713.0	10.48	5.48	47.74	10.13	407.1	0.500	15.18 (921.5)	11.76 TH&B	-	-
714.0	14.83	14.30	3.60	8.97	427.3	0.167	12.23 (930.5)	11.02 Thack Rd.	-	-
715.0	20.13	14.83	26.29	16.76	371.9	0.500	12.21 (931.5)	9.86 TH&B	2.74 (932.5)	1.50 Quigley Side Rd.

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 5 YEAR   CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	52.05	42.25	18.83	18.43	-	0.083	8.32 (981.5)	-0.33 C.N.R.	-	-
701.0	115.7	107.2	7.34	34.98	37.37	0.083	-	-	-	-
702.0	110.4	73.09	33.78	18.43	10.49	0.083	-	-	-	-
703.0	115.2	103.1	10.46	32.87	32.01	0.083	2.59 (909.5)	-0.43 Stone Church Rd.	-	-
704.0	210.1	187.4	10.81	90.50	109.9	0.167	-	-	-	-
705.0	187.4	185.4	1.06	21.86	26.80	0.0	-	-	-	-
706.0	186.2	180.1	3.25	22.40	29.10	0.083	-	-	-	-
707.0	25.79	16.38	36.50	2.99	8.56	0.083	7.80 (950.5)	5.97 Mt. Brow Blvd.	-	-
708.0	187.2	146.2	21.88	98.93	511.9	0.250	-	-	-	-
709.0	234.9	101.3	56.88	343.0	1599.0	0.667	2.74 (906.5)	-0.41 Hixon Rd.	16.25 (907.5)	8.89 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 10 YEAR　　CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	14.24	12.90	9.51	6.15	-	0.333	8.32 (981.5)	4.4 C.N.R.	-	-
701.0	51.79	50.12	3.22	19.43	37.37	0.083	-	-	-	-
702.0	11.27	11.17	0.89	2.35	10.49	0.083	-	-	-	-
703.0	25.67	24.38	5.03	9.82	32.01	0.250	2.59 (909.5)	1.05 Stone Church Rd.		
704.0	79.82	76.62	[illegible].01	49.90	109.9	0.167	-	-	-	-
705.0	76.62	76.05	0.75	11.21	26.80	0.0	-	-	-	-
706.0	76.96	76.73	0.29	10.20	29.10	0.083	-	-	-	-
707.0	16.54	11.67	29.46	2.23	8.56	0.083	7.80 (950.5)	6.32 Mt. Brow Blvd.	-	-
708.0	84.91	78.23	7.87	51.15	511.9	0.167	-	-	-	-
709.0	178.4	95.78	46.30	273.3	1599.0	0.917	2.74 (906.5)	-0.38 Hixon Rd.	16.25 (907.5)	9.45 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 10 YEAR CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	29.39	27.49	6.48	36.75	113.7	0.500	6.12 (920.5)	2.86 Albion Rd.	-	-
711.0	122.0	89.28	26.83	380.6	1998.0	1.25	9.69 (904.5) 4.11 (905.5)	5.68 Queenston Rd. 0.94 King St.	2.80 (903.5)	-1.11 Barton St.
712.0	90.41	83.44	7.71	253.2	1166.0	0.917	2.87 (901.5) 3.84 (900.5)	0.81 Burlington St. 2.73 Woodward Ave.	10.21 (902.5)	6.19 CN
713.0	15.08	7.14	52.66	18.61	407.1	0.833	15.18 (921.5)	10.58 TH&B	-	-
714.0	23.35	22.47	3.76	17.89	427.3	0.333	12.23 (930.5)	10.60 Thack Rd.		
715.0	32.32	23.35	27.76	37.39	371.9	0.750	12.21 (931.5)	7.87 TH&B	2.74 (932.5)	1.07 Quigley Side Rd.

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 10 YEAR CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	63.44	52.88	16.65	21.97	-	0.0	8.32 (981.5)	-0.43 C.N.R.	-	-
701.0	132.8	125.2	5.72	39.81	37.37	0.083	-	-	-	-
702.0	134.8	86.78	35.62	22.34	10.49	0.083	-	-	-	-
703.0	139.3	124.3	10.77	37.35	32.01	0.083	2.59 (909.5)	-0.50 Stone Church Rd.	-	-
704.0	255.1	228.6	10.39	105.5	109.9	0.167	-	-	-	-
705.0	228.6	227.9	0.31	25.66	26.80	0.0	-	-	-	-
706.0	229.0	224.4	2.01	27.30	29.10	0.0	-	-	-	-
707.0	32.46	20.54	36.72	3.63	8.56	0.0	7.80 (950.5)	5.68 Mt. Brow Blvd.	-	-
708.0	237.5	183.0	22.95	148.4	511.9	0.25	-	-	-	-
709.0	295.1	119.9	59.37	591.8	1599.0	1.00	2.74 (906.5)	-0.46 Hixon Rd.	16.25 (907.5)	6.80 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 10 YEAR CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	42.42	39.17	7.66	62.75	113.7	0.667	6.12 (920.5)	0.97 Albion Rd.	-	-
711.0	157.3	110.3	29.88	611.8	1998.0	1.67	9.69 (904.5) 4.11 (905.5)	4.97 Queenston Rd. 0.48 King St.	2.80 (903.5)	-2.73 Barton St.
712.0	110.9	105.9	4.51	321.1	1166.0	0.75	2.87 (901.5) 3.84 (900.5)	0.51 Burlington St. 2.56 Woodward Ave.	15.21 (902.5)	5.49 CN
713.0	38.97	8.80	77.42	37.12	407.1	0.667	15.18 (921.5)	9.15 TH&B	-	-
714.0	36.90	33.94	8.02	35.89	427.3	0.50	12.23 (930.5)	8.83 Thack Rd.	-	-
715.0	142.2	36.90	74.05	126.6	371.9	0.667	12.21 (931.5)	4.65 TH&B	2.74 (932.5)	-0.22 Quigley Side Rd.

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 25 YEAR CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	18.42	16.40	10.97	7.09	-	0.250	8.32 (9815)	3.4 C.N.R.	-	-
701.0	65.17	62.72	3.76	23.12	33.37	0.250	-	-	-	-
702.0	14.41	14.19	1.52	2.92	10.49	0.083	-	-	-	-
703.0	32.50	31.73	2.38	13.05	32.01	0.167	2.59 (909.5)	0.76 Stone Church Rd.	-	-
704.0	100.6	95.75	4.79	57.92	109.9	0.167	-	-	-	-
705.0	95.75	95.37	0.39	13.35	26.80	0.0	-	-	-	-
706.0	96.41	95.36	1.09	12.36	29.10	0.0	-	-	-	-
707.0	21.11	14.79	29.96	2.73	8.56	0.083	7.80 (950.5)	6.08 Mt. Brow Blvd.	-	-
708.0	106.5	100.5	5.60	49.58	511.9	0.167	-	-	-	-
709.0	223.6	104.0	53.46	380.0	1599.0	0.917	2.74 (906.5)	-0.41 Hixon Rd.	16.25 (907.5)	8.60 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 25 YEAR CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	33.03	31.22	5.49	43.60	113.7	0.500	6.12 (920.5)	1.80 Albion Rd.	-	-
711.0	133.4	97.28	27.10	453.0	1998.0	1.167	9.69 (904.5) 4.11 (905.5)	5.42 Queenston Rd. 0.77 King St.	2.80 (903.5)	-1.73 Barton St.
712.0	97.60	91.22	6.53	277.2	1167.0	0.750	2.87 (901.5) 3.84 (900.5)	0.70 Burlington St. 2.67 Woodward Ave.	10.21 (902.5)	5.94 CN
713.0	19.11	7.89	58.67	24.90	407.1	0.833	15.18 (921.5)	10.01 TH&B	-	-
714.0	25.89	25.42	1.83	21.12	427.3	0.500	12.23 (930.5)	10.46 Thack Rd.	-	-
715.0	41.44	25.89	37.52	52.28	371.9	0.833	12.21 (931.5)	7.15 TH&B	2.74 (932.5)	0.95 Quigley Side Rd.

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 25 YEAR CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	77.08	63.10	18.14	25.18	-	0.083	8.32 (981.5)	-0.49 C.N.R.	-	-
701.0	160.4	152.5	4.92	47.13	37.37	0.083	-	-	-	-
702.0	169.3	104.4	38.34	27.38	10.49	0.083	-	-	-	-
703.0	168.4	148.6	11.79	42.49	32.01	0.083	2.59 (909.5)	-0.59 Stone Church Rd.	-	-
704.0	305.1	272.9	10.57	121.6	109.9	0.167	-	-	-	-
705.0	272.9	272.2	0.26	29.62	26.80	0.0	-	-	-	-
706.0	273.5	268.3	1.91	32.15	29.10	0.0	-	-	-	-
707.0	40.75	25.21	38.12	4.34	8.56	0.0	7.80 (950.5)	5.38 Mt. Brow Blvd.	-	-
708.0	284.5	231.7	18.55	174.4	511.9	0.25	-	-	-	-
709.0	359.1	128.5	64.21	721.3	1599.0	0.833	2.74 (906.5)	-0.48 Hixon Rd.	16.25 (9[illegible]7.5)	5.72 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 25 YEAR CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	44.99	41.94	6.78	69.74	113.7	0.75	6.12 (920.5)	0.59 Albion Rd.	-	-
711.0	168.4	116.7	30.68	686.6	1998.0	1.67	9.69 (904.5) 4.11 (905.5)	4.70 Queenston Rd. 0.34 King St.	2.80 (903.5)	-3.17 Barton St.
712.0	117.0	111.5	4.69	337.7	1166.0	0.667	2.87 (901.5) 3.84 (900.5)	0.45 Burlington St. 2.52 Woodward Ave.	10.2[illegible] (902.5)	5.33 CN
713.0	48.92	9.28	1[illegible]04	45.76	407.1	0.75	15.18 (921.5)	8.65 TH&B	-	-
714.0	39.25	36.05	8.17	41.5	427.3	0.75	12.23 (930.5)	9.12 Track Rd.	-	-
715.0	143.2	39.25	72.59	154.3	371.9	0.583	12.21 (931.5)	3.96 TH&B	2.74 (932.5)	-0.30 Quigley Side Rd.

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 100 YEAR   CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	32.20	29.46	8.51	13.75	-	0.250	8.32 (981.5)	0.18 C.N.R.	-	-
701.0	109.2	105.8	3.10	34.61	37.37	0.083	-	-	-	-
702.0	25.38	24.93	1.74	5.07	10.49	0.083	-	-	-	-
703.0	58.34	54.97	5.78	21.69	32.01	0.167	2.59 (909.5)	-0.24 Stone Church Rd.	-	-
704.0	171.9	165.9	3.47	82.77	109.9	0.167	-	-	-	-
705.0	165.9	164.5	0.82	19.98	26.80	0.0	-	-	-	-
706.0	166.4	165.8	0.34	20.79	29.10	0.083	-	-	-	-
707.0	30.58	22.72	25.71	3.96	8.56	0.083	7.80 (950.5)	5.54 Mt. Brow Blvd.	-	-
708.0	186.7	136.1	27.10	166.1	511.9	0.500	-	-	-	-
709.0	336.2	133.2	60.39	780.4	1599.0	1.50	2.74 (906.5)	-0.49 Hixon Rd.	16.25 (907.5)	5.10 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORAGE: 100 YEAR CONDITION: EXISTING

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	45.04	42.98	4.58	72.34	113.7	0.667	6.12 (920.5)	0.19 Albion Rd.	-	-
711.0	174.1	128.7	26.08	818.7	1998.0	2.00	9.69 (904.5) 4.11 (905.5)	4.22 Queenston Rd. 0.09 King St.	2.80 (903.5)	-4.12 Barton St.
712.0	129.0	124.3	3.66	378.8	1166.0	0.750	2.87 (901.5) 3.84 (900.5)	0.31 Burlington St. 2.43 Woodward Ave.	10.21 (902.5)	4.97 CN
713.0	29.87	9.47	68.29	53.86	407.1	1.25	15.18 (921.5)	8.37 TH&B	-	-
714.0	37.36	35.67	4.51	39.99	427.3	0.667	12.23 (930.5)	8.48 Mack Rd.	-	-
715.0	72.31	37.36	48.34	132.0	371.9	1.167	12.21 (931.5)	4.53 TH&B	2.74 (932.5)	-0.23 Quigley Side Rd.

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 100 YEAR CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
601.1	103.7	85.82	17.21	31.93	-	0.083	8.32 (981.5)	-0.63 C.N.R.	-	-
701.0	195.2	191.9	1.66	57.72	37.37	0.0	-	-	-	-
702.0	224.3	134.4	40.09	35.95	10.49	0.083	-	-	-	-
703.0	223.5	196.8	11.97	52.70	32.01	0.083	2.59 (909.5)	-0.73 Stone Church Rd.	-	-
704.0	389.5	352.1	9.61	150.3	109.9	0.167	-	-	-	-
705.0	352.1	351.5	0.16	36.71	26.80	0.0	-	-	-	-
706.0	353.5	348.2	1.49	41.00	29.10	0.0	-	-	-	-
707.0	54.49	35.72	34.44	6.34	8.56	0.083	7.80 (950.5)	4.08 Mt. Brow Blvd.	-	-
708.0	376.6	330.6	12.22	227.2	511.9	0.167	-	-	-	-
709.0	525.8	148.8	71.70	504.4	1599.0	1.167	2.74 (906.5)	-0.57 Hixon Rd.	16.25 (907.5)	2.85 TH&B

TABLE SET NO. 3

ANALYSIS OF STREAM REACHES FOR STORAGE AND EMBANKMENT OVERTOPPING

STORM: 100 YEAR   CONDITION: FUTURE

REACH NO.	PEAK FLOWS (CMS)		% PEAK REDUCTION	STORAGE (1000 M**3)		LAG (HR)	MAJOR STRUCTURE FLOW CONDITION			
							1ST STRUCTURE DESCRIPTION		2ND STRUCTURE	
	INFLOW	OUTFLOW		USED	MAX.		EMBANKMENT HEIGHT (M)	FREEBOARD (M)	EMBANKMENT HEIGHT (M)	FREEBOARD (M)
710.0	52.26	50.25	3.86	90.66	113.7	0.833	6.12 (920.5)	-0.48 Albion Rd.	-	-
711.0	195.4	146.7	24.94	1017.0	1998.0	2.33	9.69 (904.5) 4.11 (905.5)	2.99 Queenston Rd. -0.41 King St.	2.80 (903.5)	-4.82 Barton St.
712.0	147.1	142.5	3.1[illegible]	438.0	1166.0	0.75	2.87 (901.5) 3.84 (900.5)	0.12 Burlington St. 2.31 Woodward Ave.	10.21 (902.5)	4.46 CN
713.0	68.57	10.08	85.[illegible]1	79.01	407.1	1.083	15.18 (921.5)	7.78 TH&B	-	-
714.0	47.35	42.[illegible]1	10.42	67.02	427.3	1.00	12.23 (930.5)	7.25 Thack Rd.	-	-
715.0	247.3	47.35	80.86	249.6	371.9	0.917	12.21 (931.5)	1.42 TH&B	2.74 (932.5)	-0.48 Quigley Side Rd.

Table Set No. 4:

Locations and Conditions of Erosive Velocities

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
501.1	66.0	-	5.51	-	5.68	-	5.80	-	6.05
	7000.0	7.34	7.50	8.42	7.05	9.02	6.83	7.29	6.55
	7001.0	5.27	13.62	6.06	14.25	6.44	15.00	9.76	16.10
	7002.0	7.66	11.97	8.82	12.59	9.53	13.33	11.23	14.51
	7003.0	8.29	-	9.60	-	10.31	-	-	-
	7004.0	-	-	-	-	-	-	6.80	5.03
	7005.0	-	11.74	-	11.74	-	11.93	-	12.47
	7006.0	-	6.41	-	6.86	-	7.36	5.78	8.05
702.0	66.0	-	-	-	-	-	-	-	-
	67.0	7.91	10.25	8.71	10.92	9.27	11.83	9.48	13.07
	68.0	7.71	10.91	8.45	11.59	8.33	12.14	9.89	13.20
	69.0	-	5.26	-	5.39	-	5.50	5.04	5.75
	70.0	-	-	-	-	-	-	-	5.06
	71.0	-	-	-	5.23	-	5.42	-	5.76
	72.0	-	-	-	-	-	-	-	-
	73.0	8.08	-	9.08	-	9.71	-	-	-

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
703.0	63.0	-	5.08	-	5.74	-	6.38	-	7.50
	64.0	-	5.57	-	5.97	-	6.36	-	7.53
	65.0	5.32	9.35	6.14	9.99	5.97	10.62	7.44	11.68
	66.0	-	-	-	-	-	-	-	-
704.0	59.0	8.99	14.02	10.71	14.47	11.91	14.96	13.65	15.91
	60.0	5.22	5.30	5.23	5.29	5.18	5.27	5.30	5.28
	61.0	-	-	-	-	-	-	-	-
	62.0	-	-	-	-	-	-	-	-
	63.0	-	5.08	-	5.74	-	6.38	-	7.50
705.0	56.8	10.74	17.22	12.61	18.23	13.79	19.42	16.57	20.78
	57.0	7.05	13.89	9.07	15.33	10.12	16.52	13.15	18.36
	58.0	10.67	14.63	11.69	15.58	11.95	16.44	14.11	17.34
	59.0	8.99	14.02	10.71	14.47	11.91	14.96	13.65	15.91

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
706.0	51.0	11.56	14.91	12.30	15.17	12.96	15.92	14.61	16.90
	52.0	11.74	14.22	12.82	15.09	13.39	16.16	13.96	16.94
	53.0	12.08	17.12	13.66	17.28	14.45	18.40	16.74	19.76
	54.0	11.78	17.00	13.23	18.14	14.16	19.19	16.57	20.75
	55.0	11.86	17.67	13.72	18.74	14.64	19.34	17.29	21.05
	56.0	11.21	16.47	12.89	17.65	13.86	18.73	16.05	20.34
	56.5	10.75	15.90	12.26	16.84	13.14	17.70	15.37	18.91
707.0	2000.0	8.89	10.56	9.60	11.16	10.22	11.91	11.57	12.76
	2001.0	8.80	10.60	9.61	11.32	10.28	11.97	11.59	13.23
	2002.0	9.15	11.08	10.01	11.77	10.75	12.51	12.13	13.95
	2003.0	7.62	9.42	8.38	10.17	9.09	10.92	10.54	12.30
	2004.0	-	-	-	-	-	-	-	-
	2005.0	9.06	11.17	10.00	12.01	10.81	12.83	12.41	14.30
	2006.0	7.30	8.67	7.89	9.26	8.43	9.74	9.53	10.91

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
708.0	42.0	10.95	12.01	9.68	9.73	10.40	6.82		
	43.0	7.69	11.99	9.61	12.88	10.34	13.53	-	-
	44.0	10.22	10.95	11.06	11.09	11.94	12.19	7.27	-
	45.0	10.38	10.91	9.23	10.71	9.16	11.38	10.68	13.65
	46.0	9.49	10.19	10.70	10.39	11.48	11.57	10.55	12.41
	47.0	7.97	11.43	9.28	12.06	9.77	13.40	10.19	12.35
	48.0	10.86	12.68	12.42	13.30	13.13	13.31	10.69	15.27
	49.0	12.12	16.00	13.76	16.85	14.63	15.42	12.51	14.50
	50.0	11.30	15.78	13.32	16.79	14.11	17.84	15.65	15.39
	51.0	11.56	14.91	12.30	15.00	12.96	15.92	15.47	19.18
								14.61	16.90
709.0	32.0	-	5.72	5.42	5.95	5.61	6.17	5.95	5.85
	33.0	-	-	-	-	-	-	-	-
	34.0	8.95	6.91	6.65	5.65	6.21	5.48	-	-
	35.0	6.20	7.48	7.30	6.95	7.28	6.81	6.09	-

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
709.0 (cont'd)	36.0	-	5.41	5.23	6.22	5.58	6.61	6.81	7.23
	37.0	5.21	6.42	6.25	7.26	6.61	7.64	7.84	8.21
	38.0	-	-	-	-	-	-	-	-
	39.0	-	-	-	-	-	-	-	-
	40.0	11.32	-	-	-	-	-	-	-
	41.0	8.73	7.55	11.72	-	5.87	-	-	-
	42.0	10.95	12.01	9.68	9.73	10.40	6.82	-	-
713.0	1003.0	5.51	-	5.11	-	-	-	-	-
	1004.0	7.27	-	-	-	-	-	-	-
	1005.0	7.57	8.28	8.06	8.60	8.37	8.55	8.84	-
	1006.0	6.38	7.44	7.18	7.66	7.33	8.08	7.76	8.47
	1007.0	-	-	-	-	-	-	-	-
	1008.0	7.98	-	-	-	-	-	-	-
	1009.0	5.51	7.74	7.50	7.99	7.69	8.10	8.16	-
	1010.0	-	-	-	-	-	-	-	-
	1011.0	7.18	7.88	7.63	8.16	7.88	8.30	8.36	8.48
	1012.0	8.08	9.01	8.68	9.33	9.02	9.47	9.53	9.71

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
715.0	1111.0	7.16	9.19	8.35	10.25	8.82	10.34	10.02	10.57
	1112.0	-	-	-	-	-	-	-	-
	1113.0	5.63	-	-	-	-	-	-	-
	1114.0	9.59	12.04	11.05	7.50	11.39	-	-	-
	1115.0	9.95	12.05	11.51	12.46	11.56	-	6.73	-
	1116.0	-	-	-	-	-	12.55	12.43	5.71
	1117.0	5.21	5.79	5.66	5.56	5.74	5.69	5.59	6.38
	1118.0	9.73	12.27	11.22	12.86	11.58	13.10	12.91	13.66
714.0	1003.0	5.51	-	5.11	-	-	-	-	-
	1100.0	8.54	5.71	9.69	-	5.41	-	-	-
	1101.0	-	6.04	5.13	5.40	5.75	-	-	-
	1102.0	9.52	5.14	10.46	-	10.83	6.47	-	-
	1103.0	7.82	10.21	9.36	9.80	9.77	12.23	8.21	-
	1104.0	9.98	12.31	11.40	12.98	11.84	13.20	13.18	-
	1105.0	9.60	12.20	10.99	9.96	11.44	10.23	10.22	9.41
	1106.0	6.86	8.40	8.04	9.20	8.12	9.44	9.41	9.96

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (> 5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
714.0 (cont'd)	1107.0	5.54	8.23	7.02	8.70	7.64	8.92	8.87	9.64
	1108.0	10.04	11.55	10.80	10.40	11.25	10.62	10.60	10.72
	1109.0	-	-	-	-	-	5.05	5.03	5.35
	1110.0	10.47	11.53	11.69	11.16	12.34	11.15	11.15	11.34
	1111.0	7.16	9.19	8.35	10.25	8.82	10.34	10.02	10.57
710.0	32.0	-	5.72	5.42	5.95	5.61	6.17	5.95	5.85
	1000.0	-	-	-	-	-	-	-	-
	1001.0	-	-	-	-	-	-	-	-
	1002.0	-	-	-	-	-	-	-	-
	1003.0	5.51	-	5.11	-	-	-	-	-
711.0	18.0	-	-	-	-	-	-	-	-
	19.0	6.79	-	-	-	-	-	-	-
	20.0	-	-	-	-	-	-	-	-
	21.0	-	-	-	-	-	-	-	-
	22.0	-	-	-	-	-	-	-	-
	23.0	11.15	9.59	13.54	-	10.84	-	-	-

TABLE SET NO. 4

LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
711.0 (cont'd)	24.0	6.92	6.73	6.25	6.09	6.46	-	-	-
	25.0	8.54	9.72	9.73	9.90	9.86	7.53	-	-
	26.0	7.85	9.11	9.06	10.18	9.50	11.28	8.66	7.29
	27.0	-	-	-	-	-	-	-	-
	28.0	-	-	-	-	-	-	-	-
	29.0	-	-	-	-	-	-	-	-
	30.0	11.24	11.35	11.36	10.09	9.88	9.94	7.85	-
	31.0	8.57	10.13	10.08	12.66	11.79	13.33	13.63	11.72
	32.0	-	5.72	5.42	5.95	5.61	6.17	5.95	5.85
712.0	0.0	-	-	-	-	-	-	-	-
	1.0	5.76	9.37	9.35	10.15	9.63	10.32	10.68	11.17
	2.0	9.57	10.87	10.86	11.73	11.18	11.92	12.32	12.87
	3.0	-	5.06	5.05	5.58	5.25	5.68	5.85	5.99
	4.0	-	-	-	5.01	-	5.11	5.33	5.62
	5.0	-	-	-	-	-	-	-	-
	6.0	-	-	-	-	-	-	-	-

TABLE SET NO. 4

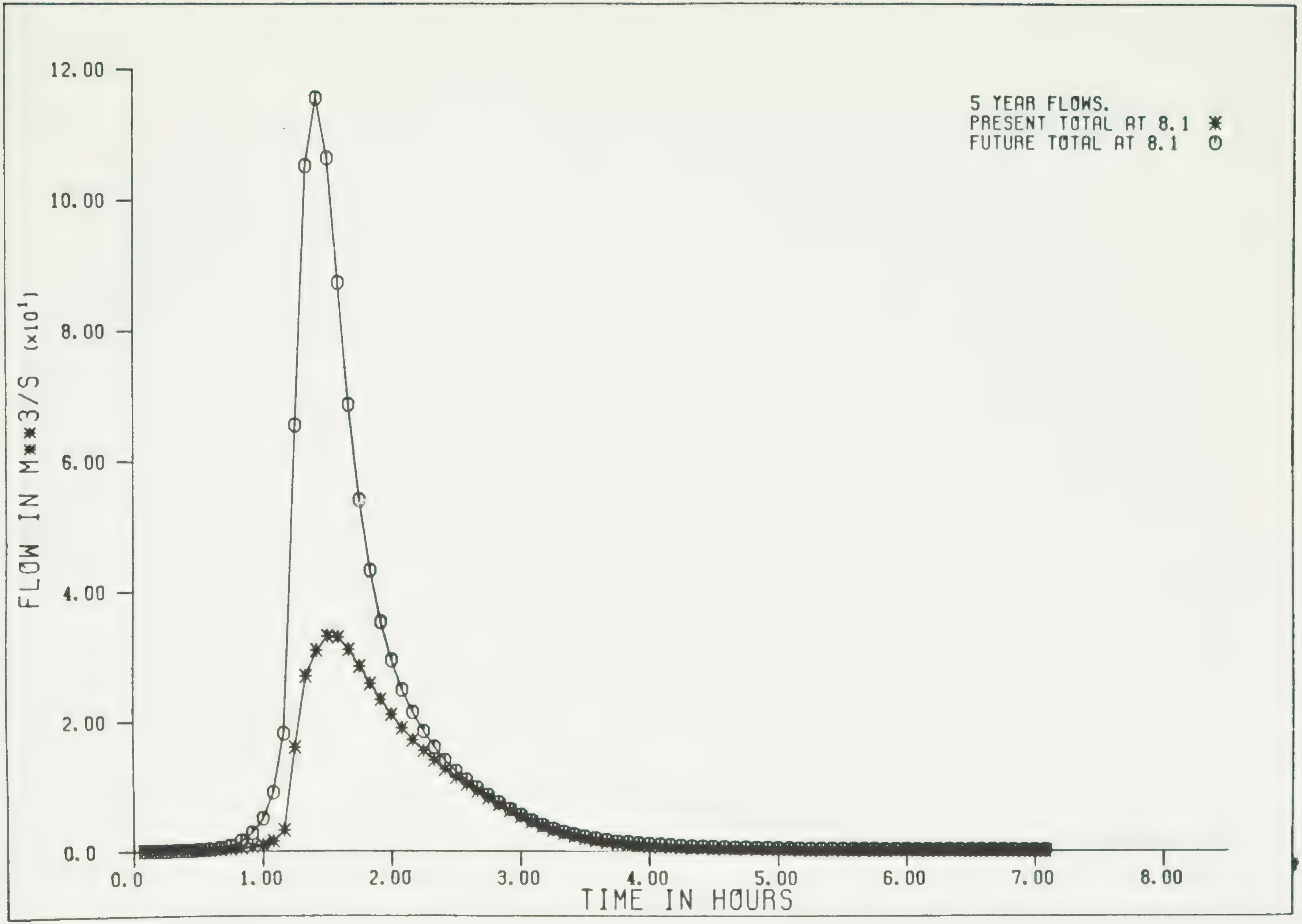
LOCATIONS AND CONDITIONS OF EROSIVE VELOCITIES

REACH	SECT. NO.	CHANNEL VELOCITIES FOR VARIOUS CONDITIONS (FT/S) (>5 FT/S)							
		5 YEAR STORM		10 YEAR STORM		25 YEAR STORM		100 YEAR STORM	
		EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE	EXISTING	FUTURE
[illegible]12.0 (cont'd)	7.0	-	-	-	-	-	-	-	-
	8.0	-	-	-	-	-	-	-	-
	9.0	-	-	-	-	-	-	-	-
	10.0	6.42	7.79	7.78	8.76	8.13	8.98	9.51	10.28
	11.0	-	5.61	5.60	6.16	5.80	6.28	6.55	6.93
	12.0	-	5.82	5.81	6.51	6.06	6.66	7.00	7.46
	13.0	-	-	-	-	-	-	-	-
	14.0	-	-	-	-	-	-	-	-
	15.0	-	-	-	-	-	-	-	-
	16.0	-	-	-	-	-	-	-	-
	17.0	-	-	-	-	-	-	-	-
	18.0	-	-	-	-	-	-	-	-

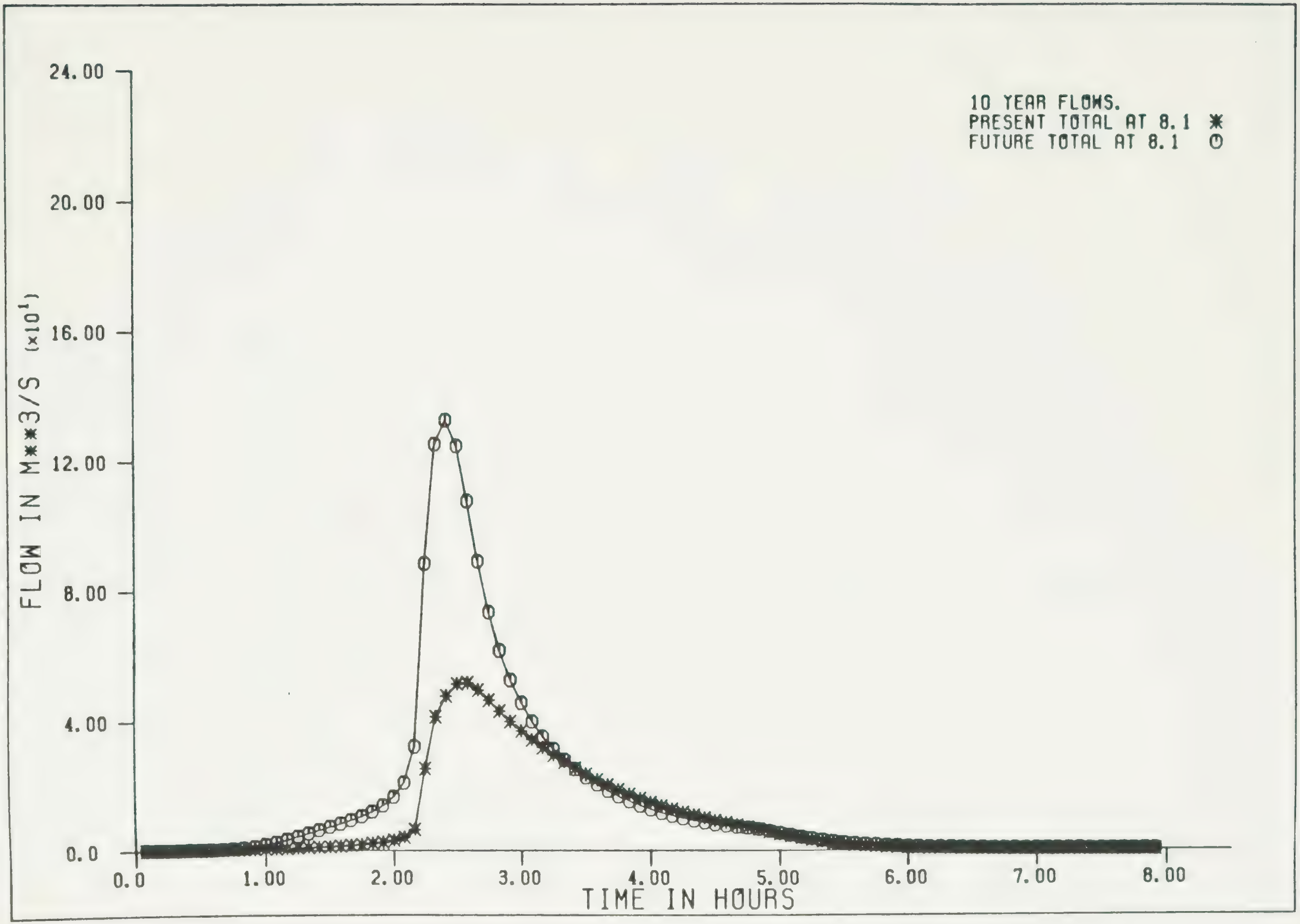
APPENDIX B:

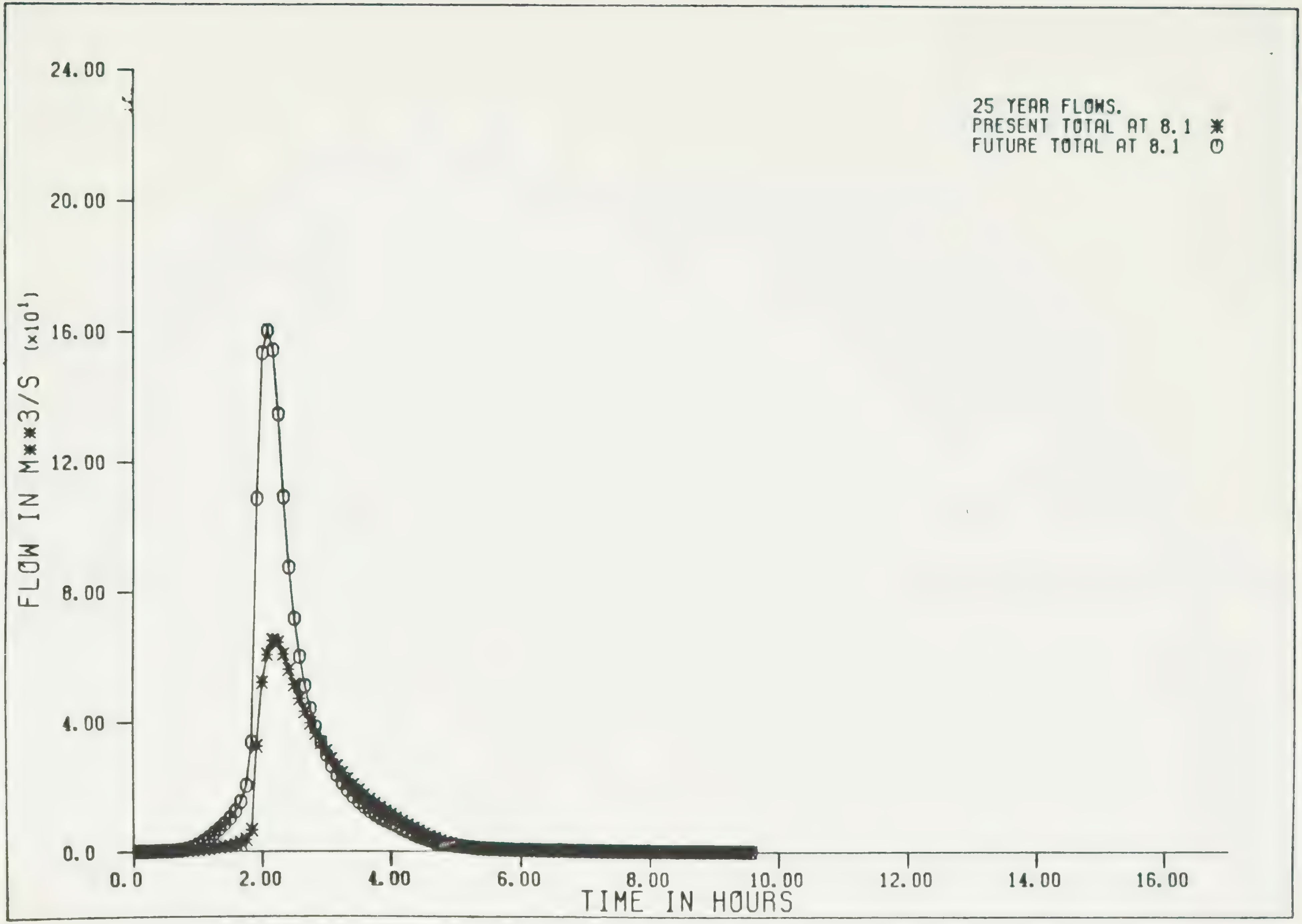
PLOTTED HYDROGRAPHS

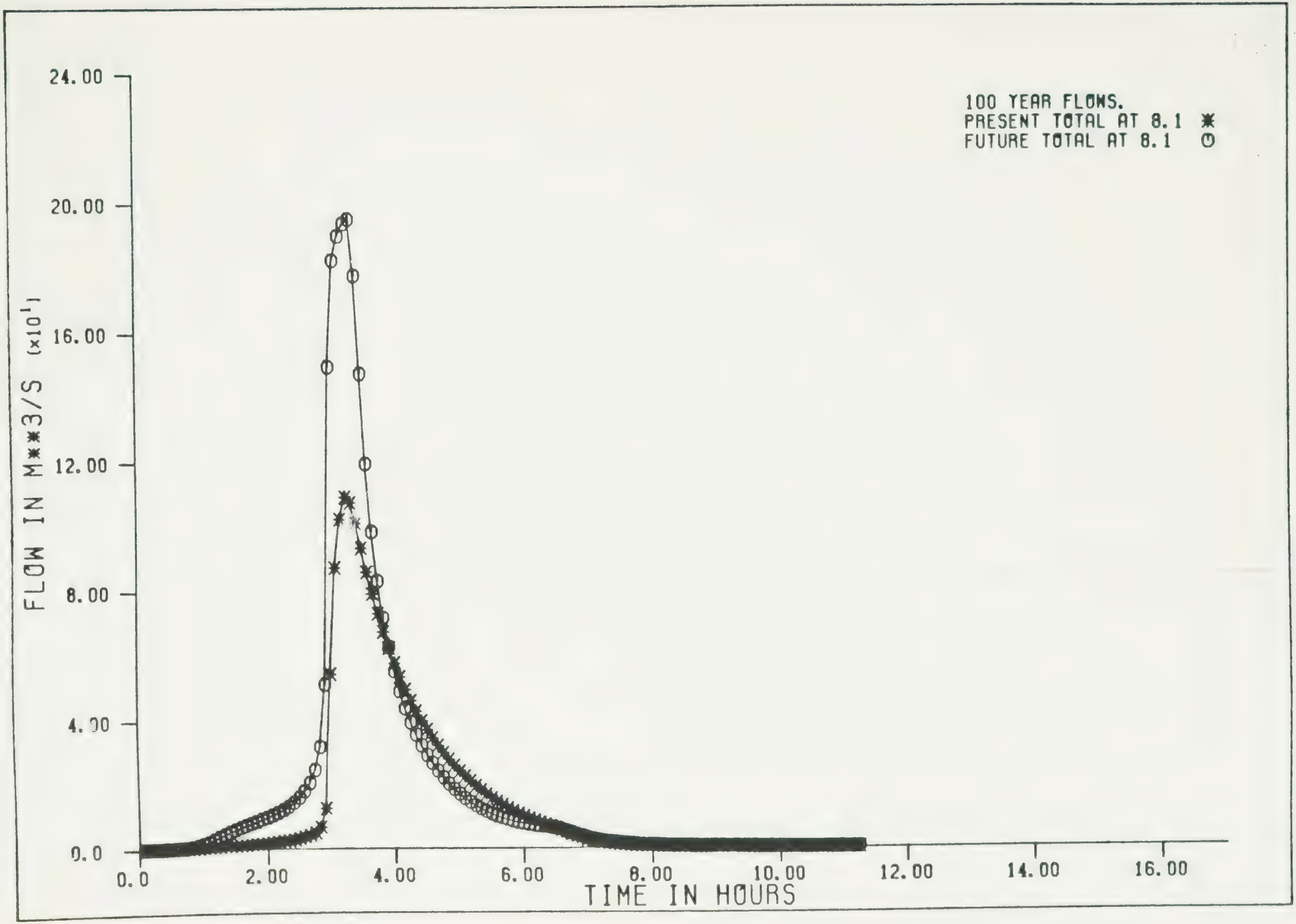
Hydrograph Set No. 1:
Existing vs Future (no controls) Runoff
Hydrographs at Selected Locations

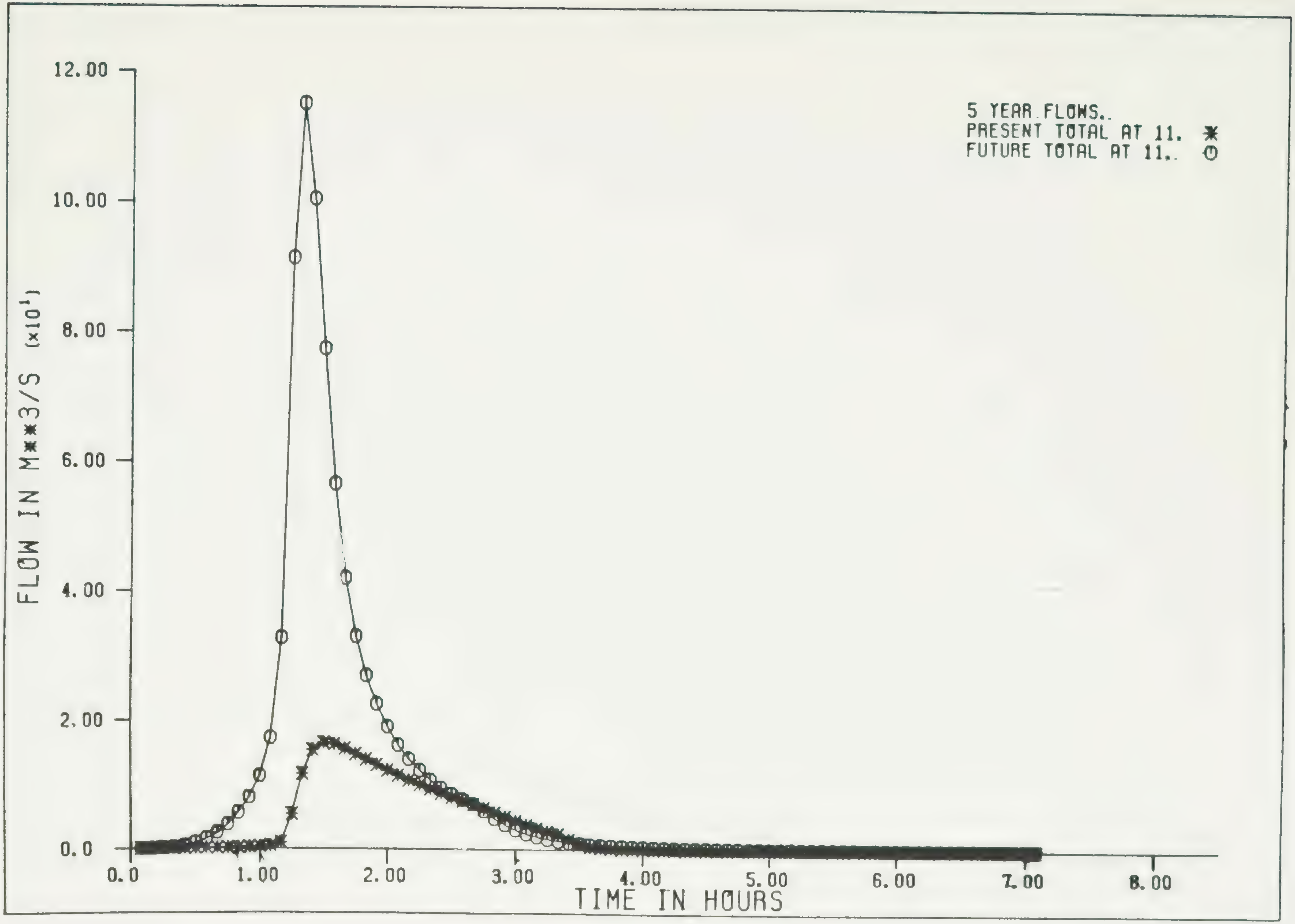


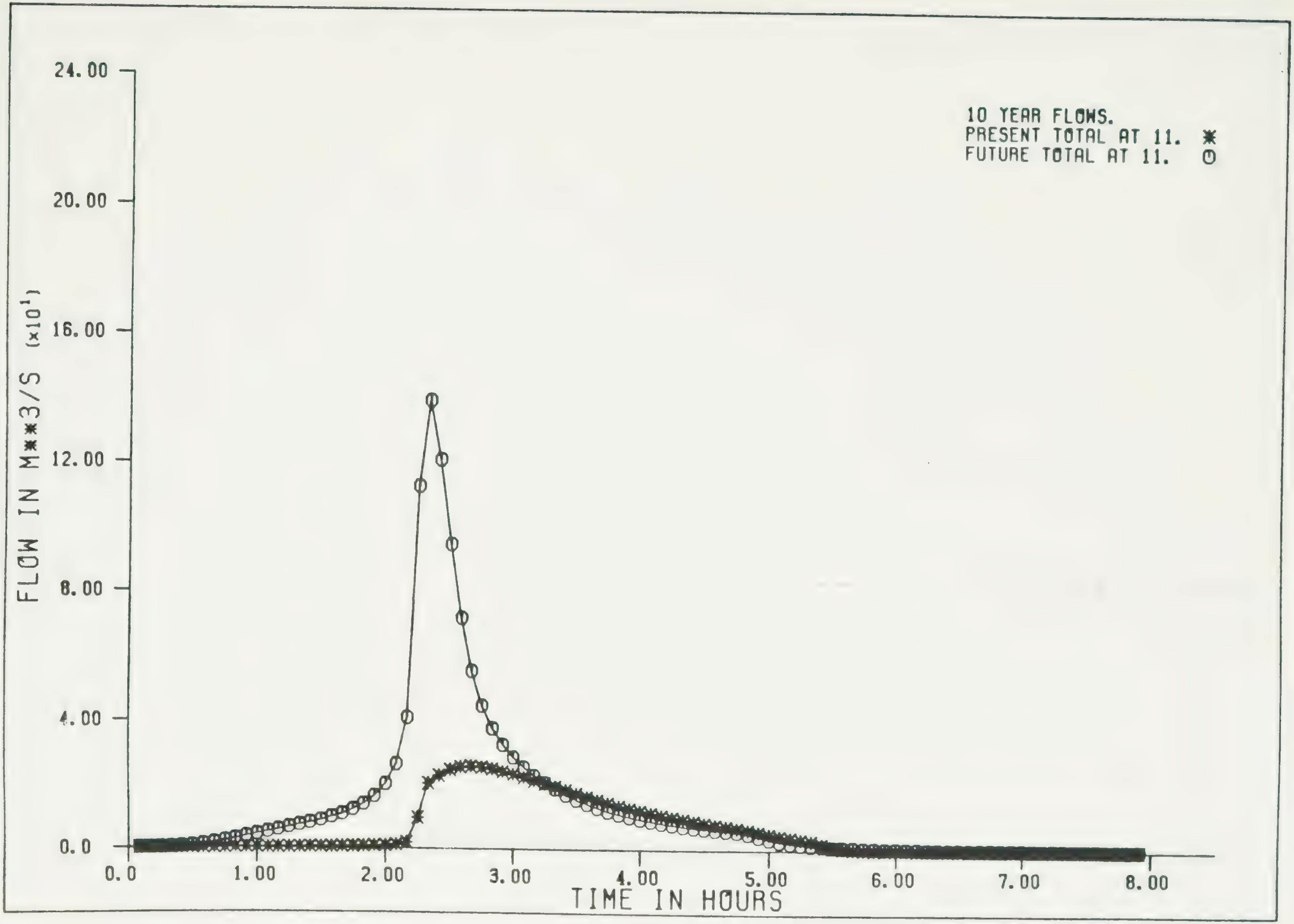
5 YEAR FLOWS.
PRESENT TOTAL AT 8.1 ✱
FUTURE TOTAL AT 8.1 ⊖
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

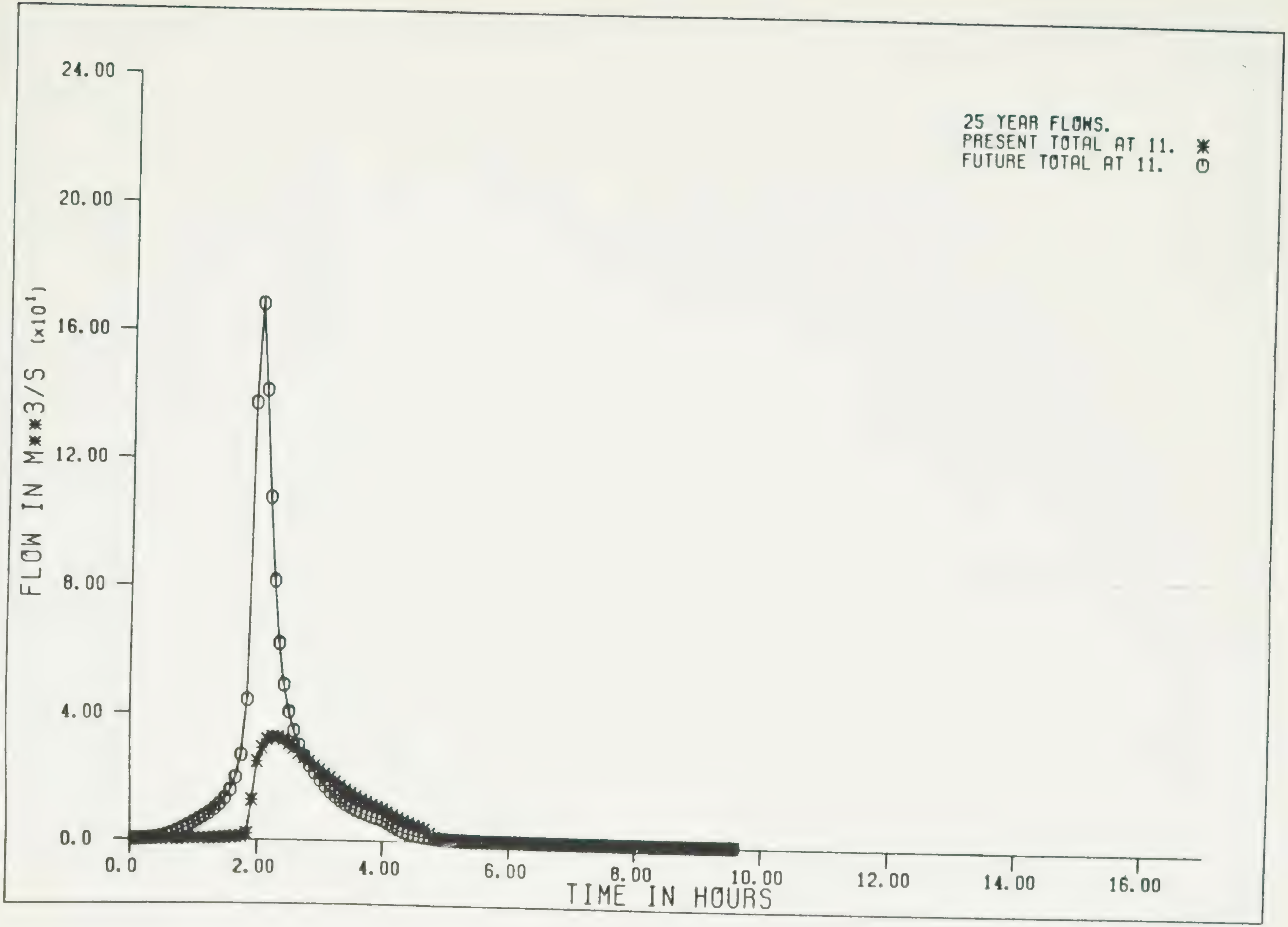

10 YEAR FLOWS.
PRESENT TOTAL AT 8.1 ✱
FUTURE TOTAL AT 8.1 ⊖
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

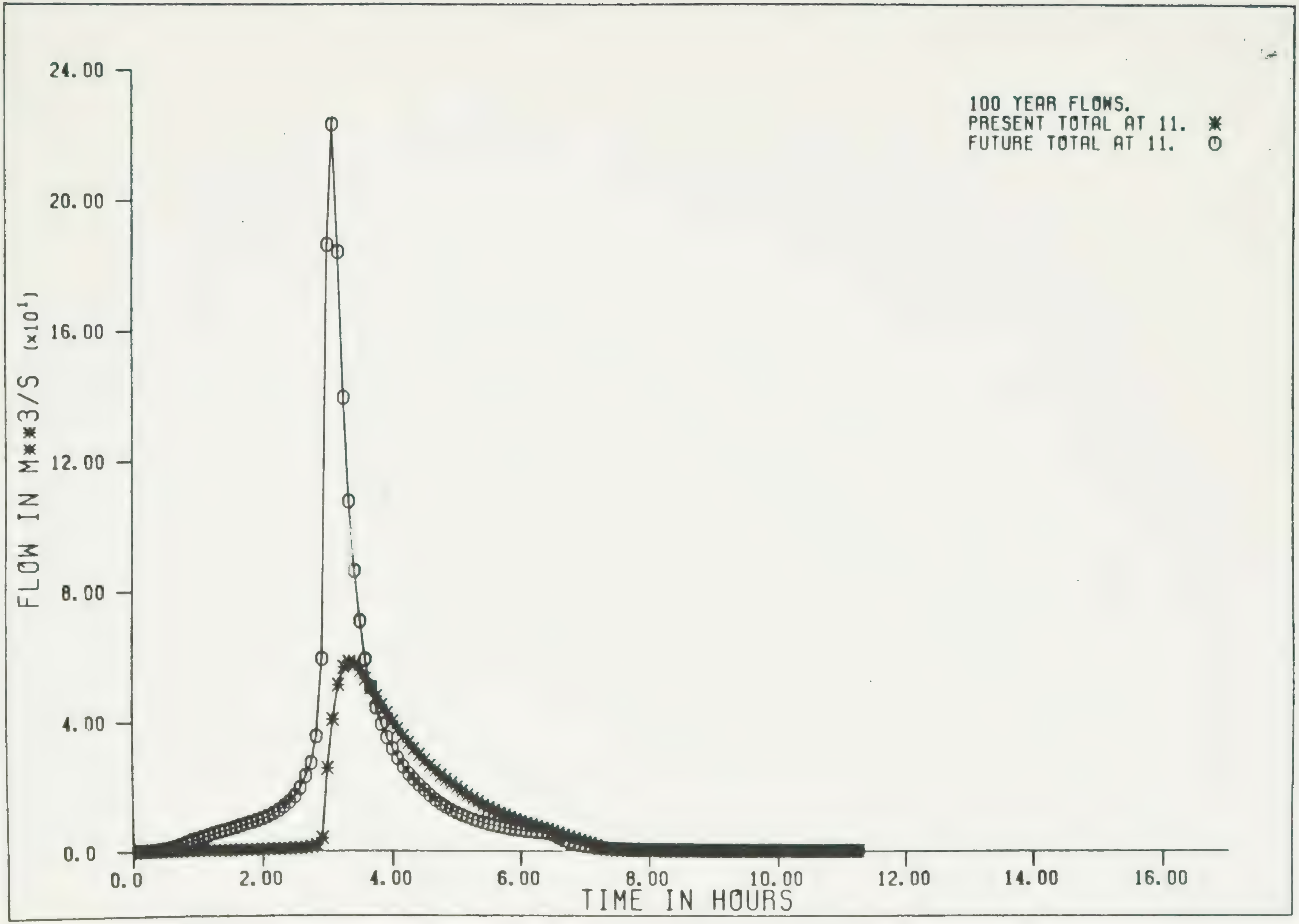

25 YEAR FLOWS.
PRESENT TOTAL AT 8.1 *
FUTURE TOTAL AT 8.1 O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

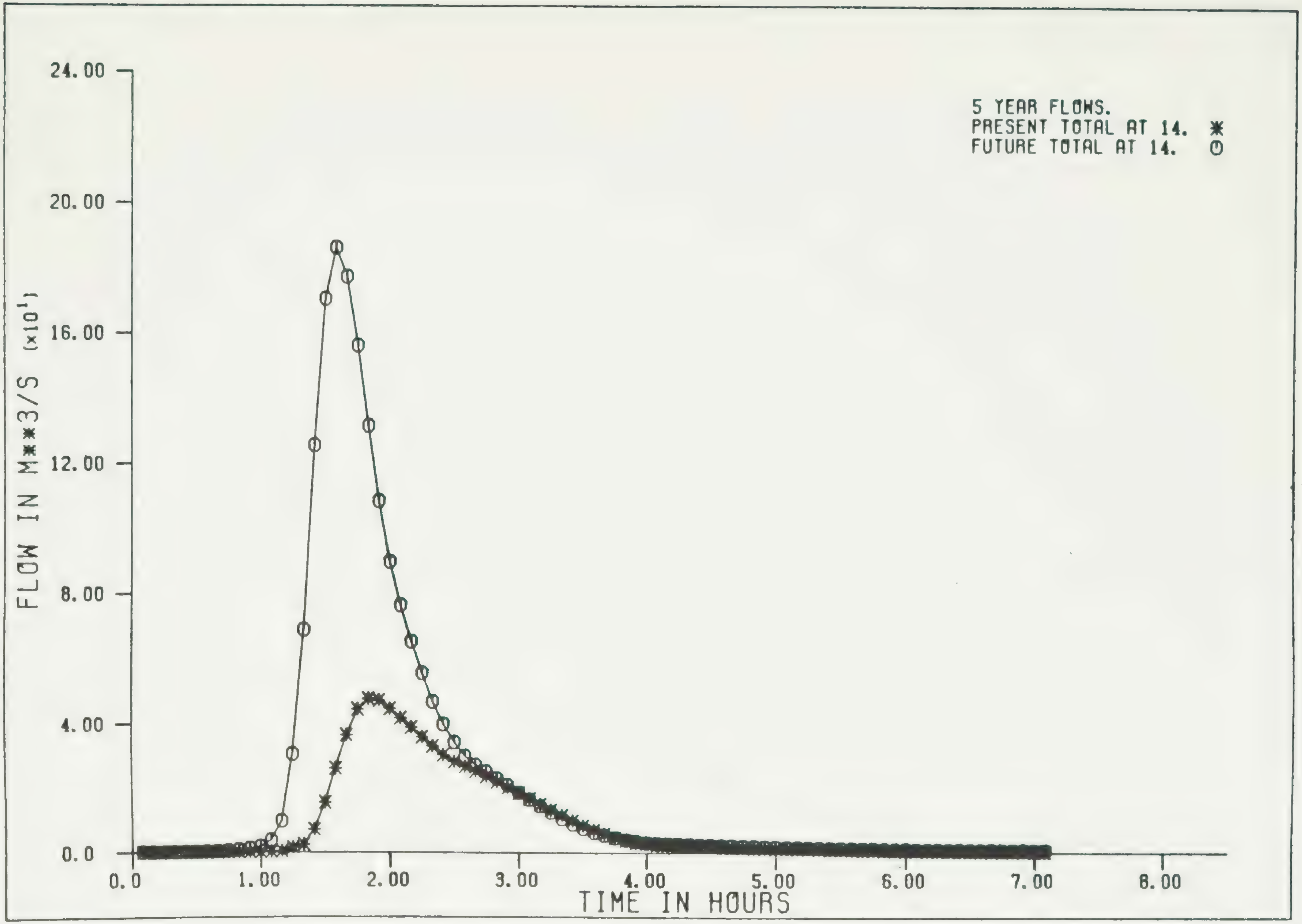

100 YEAR FLOWS.
PRESENT TOTAL AT 8.1
FUTURE TOTAL AT 8.1
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

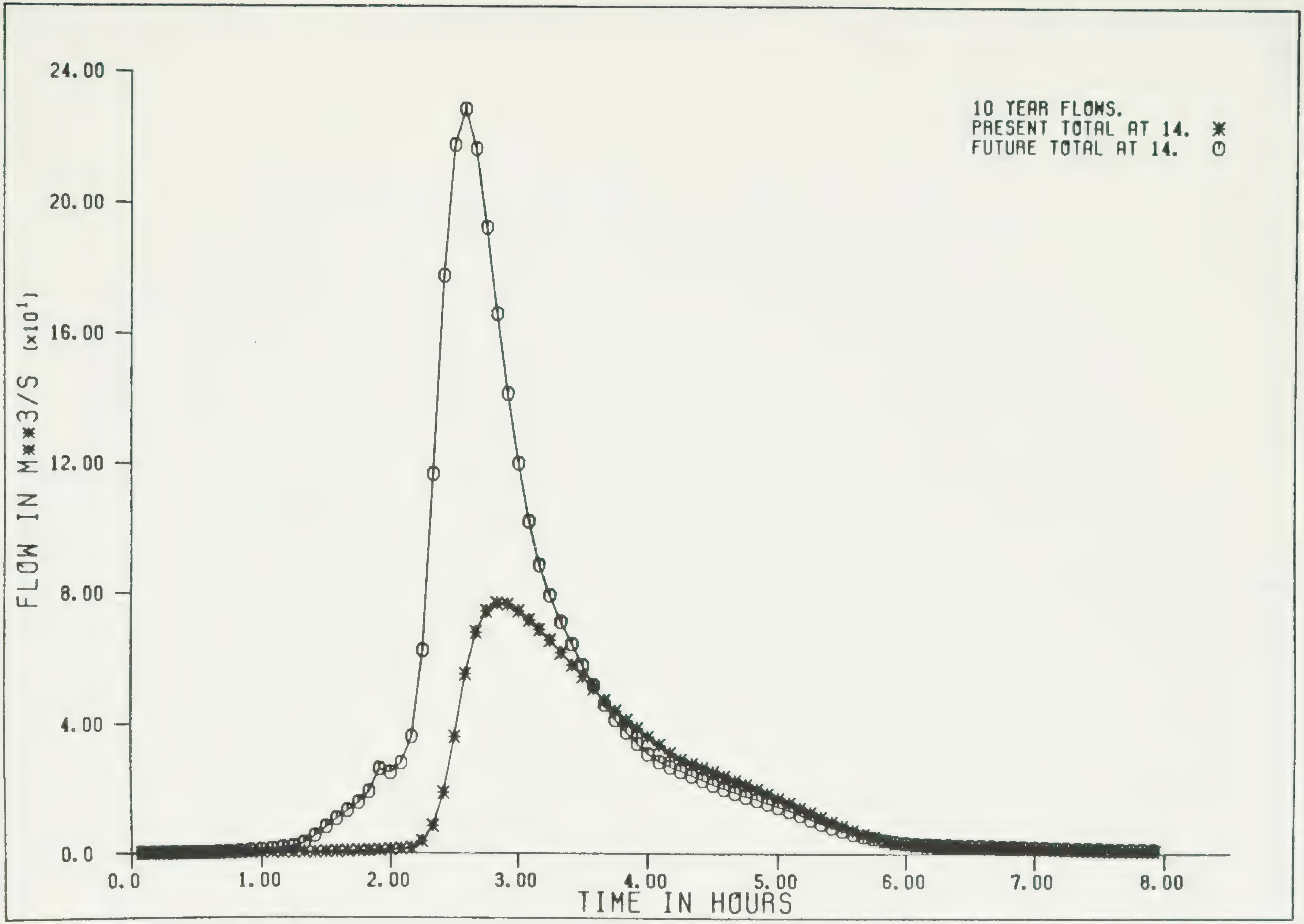

5 YEAR FLOWS..
PRESENT TOTAL AT 11.
FUTURE TOTAL AT 11..
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

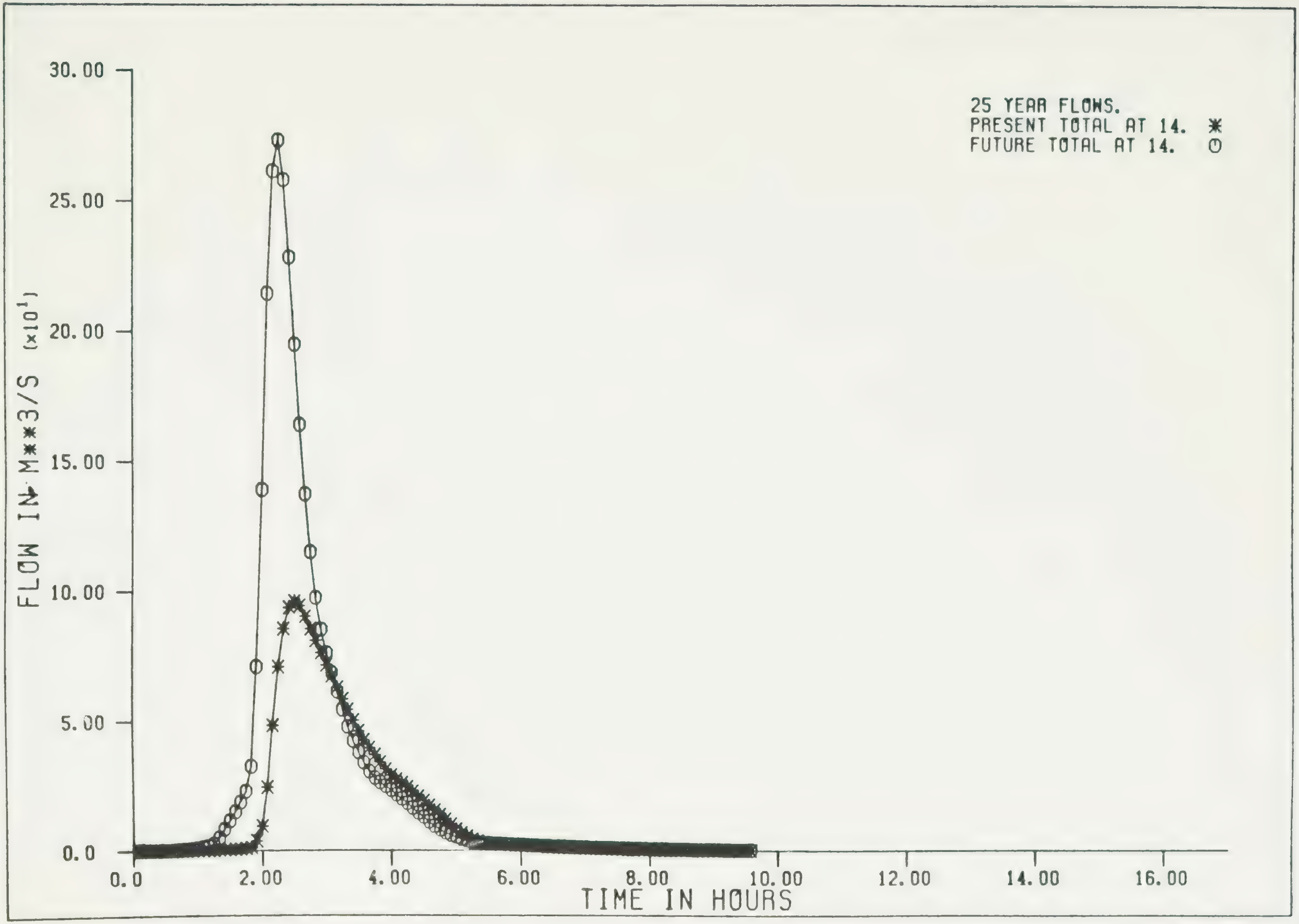

10 YEAR FLOWS.
PRESENT TOTAL AT 11. *
FUTURE TOTAL AT 11. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


25 YEAR FLOWS.
PRESENT TOTAL AT 11. *
FUTURE TOTAL AT 11. O
FLOW IN M**3/S (x10^1)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

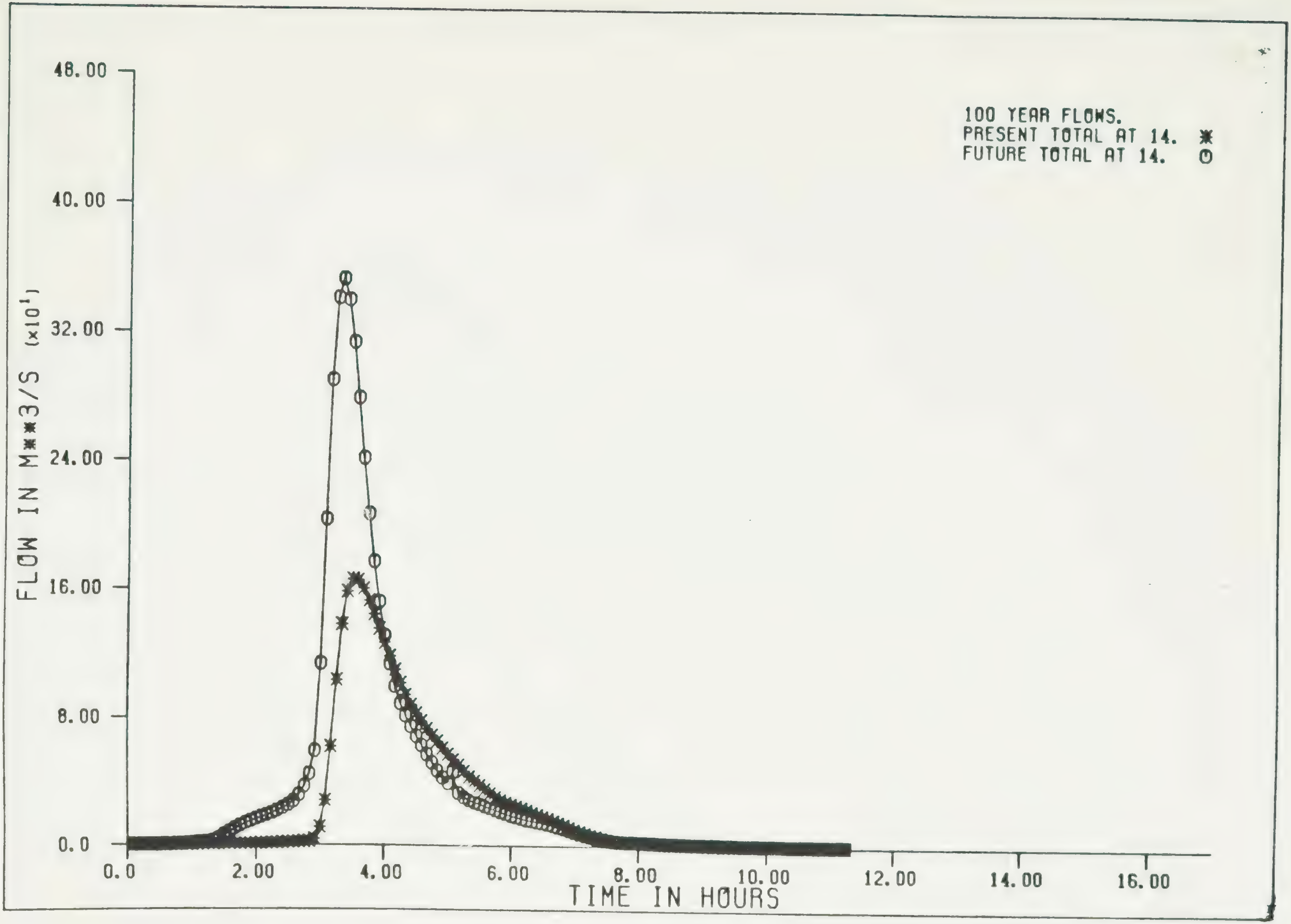

100 YEAR FLOWS.
PRESENT TOTAL AT 11. *
FUTURE TOTAL AT 11. O
FLOW IN M**3/S (x10¹)
TIME IN HOURS
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00


5 YEAR FLOWS.
PRESENT TOTAL AT 14. *
FUTURE TOTAL AT 14. O
24.00
20.00
16.00
12.00
8.00
4.00
0.0
FLOW IN M**3/S (x10¹)
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

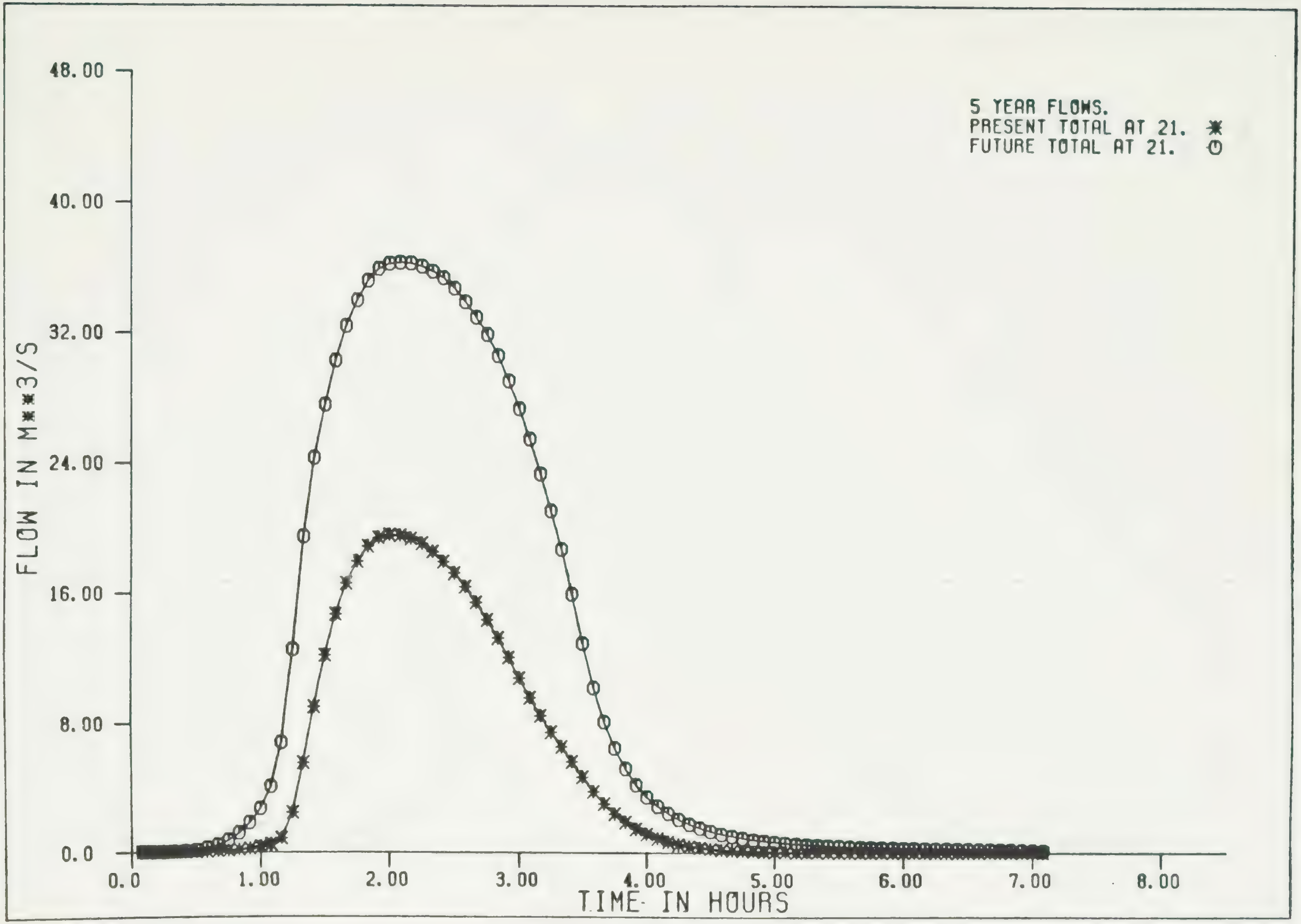

10 YEAR FLOWS.
PRESENT TOTAL AT 14. *
FUTURE TOTAL AT 14. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS



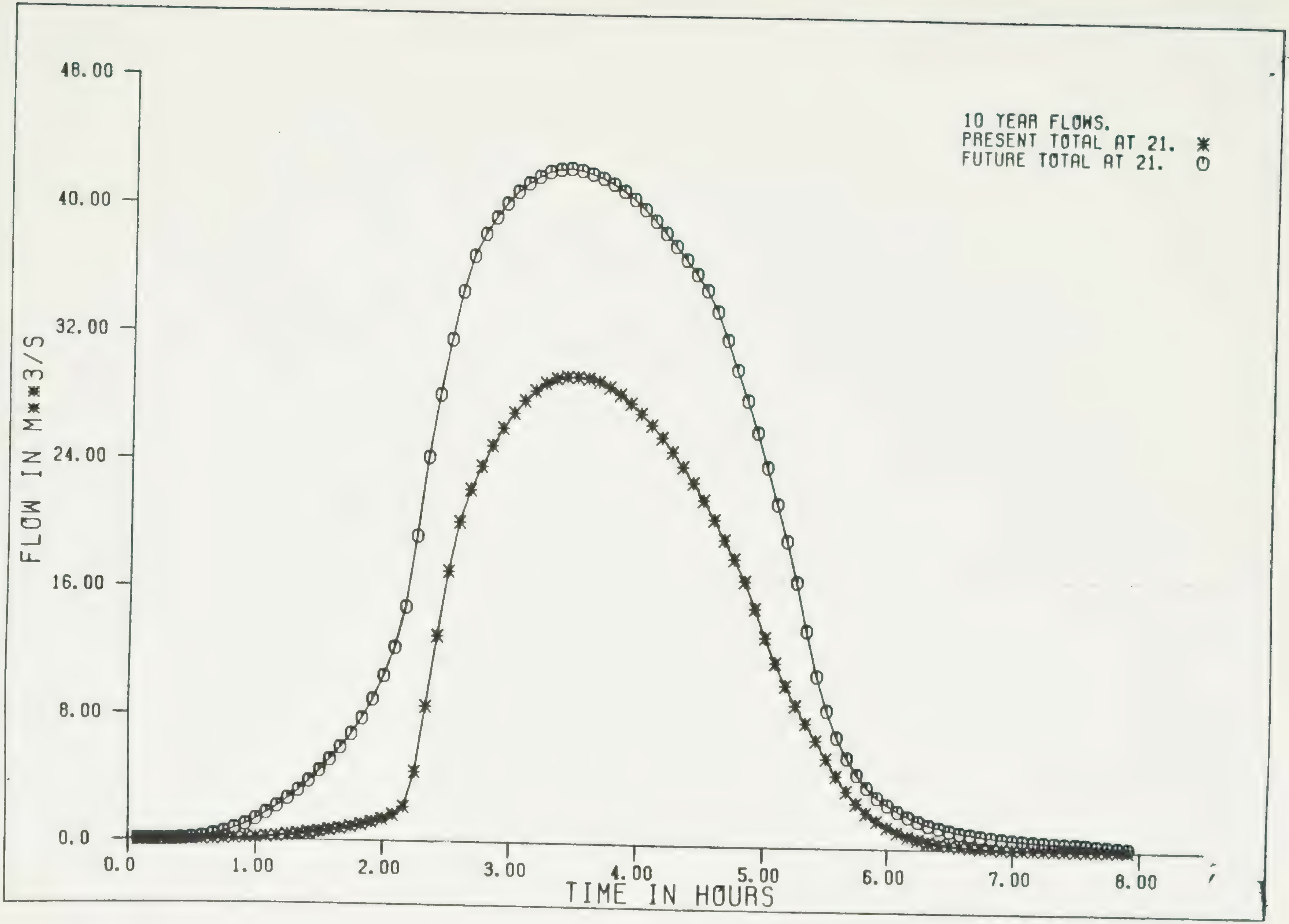
25 YEAR FLOWS.
PRESENT TOTAL AT 14. *
FUTURE TOTAL AT 14. O
FLOW IN M**3/S (x10¹)
30.00
25.00
20.00
15.00
10.00
5.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

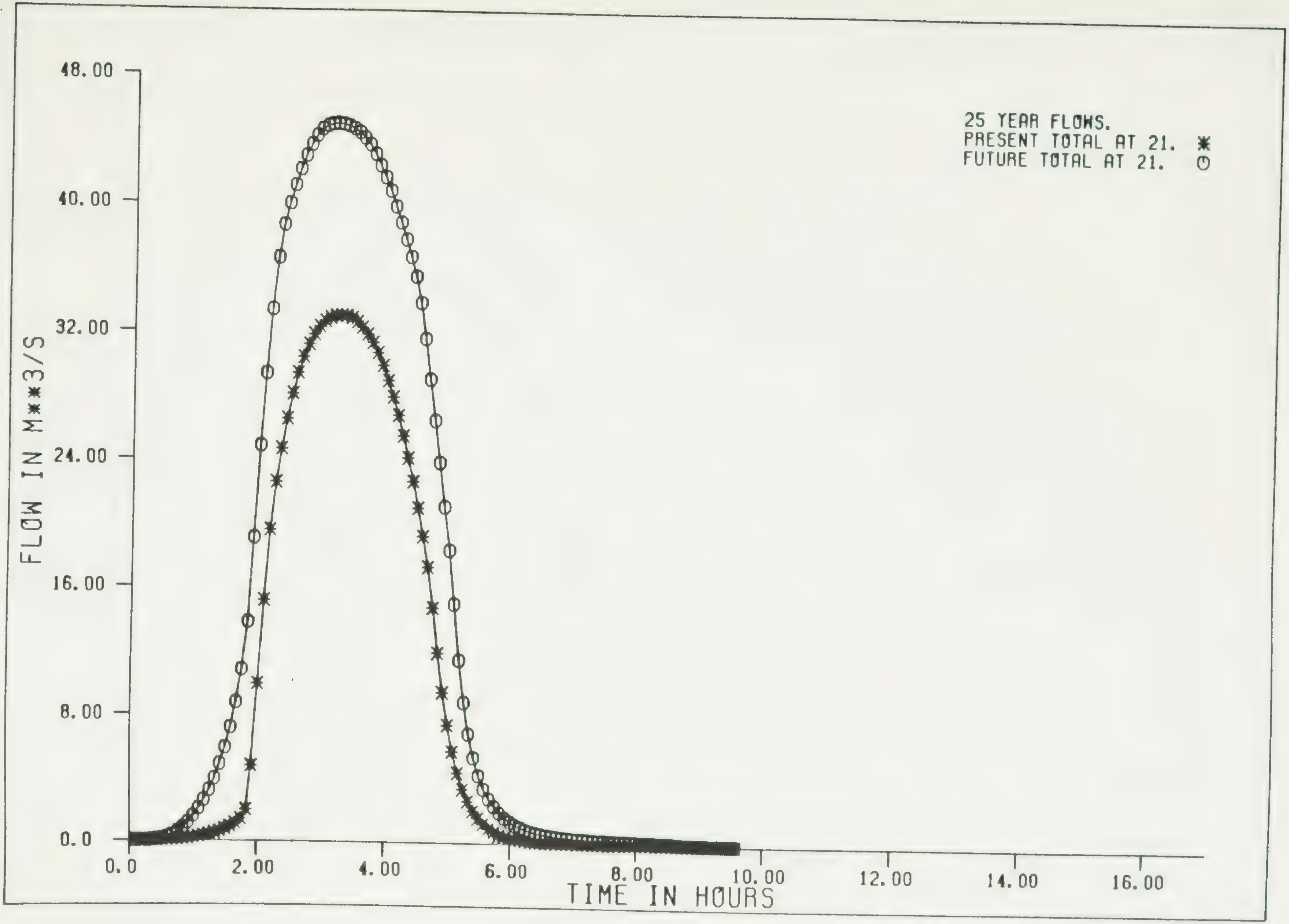


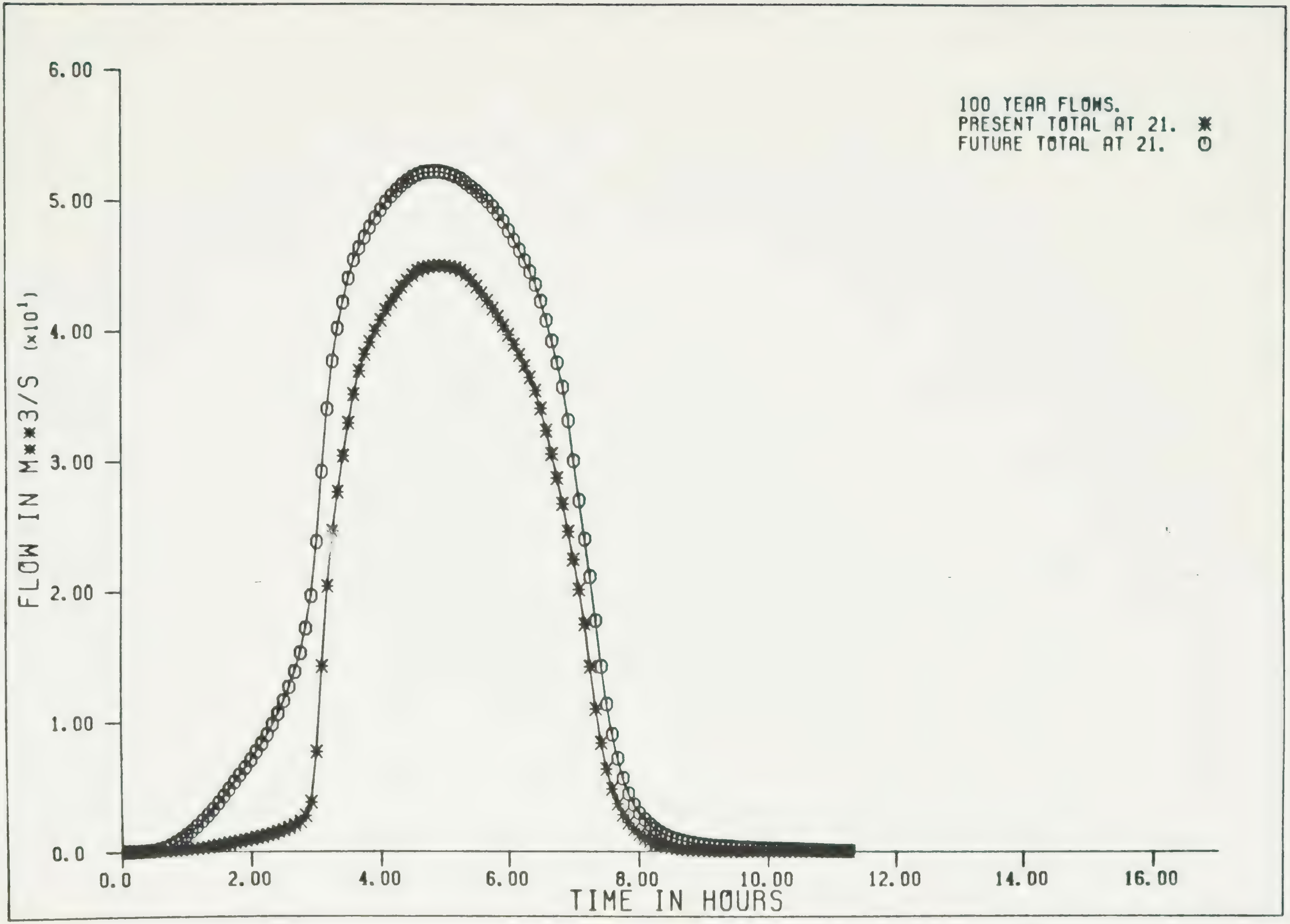
100 YEAR FLOWS.
PRESENT TOTAL AT 14. *
FUTURE TOTAL AT 14. O
FLOW IN M**3/S (x10¹)
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

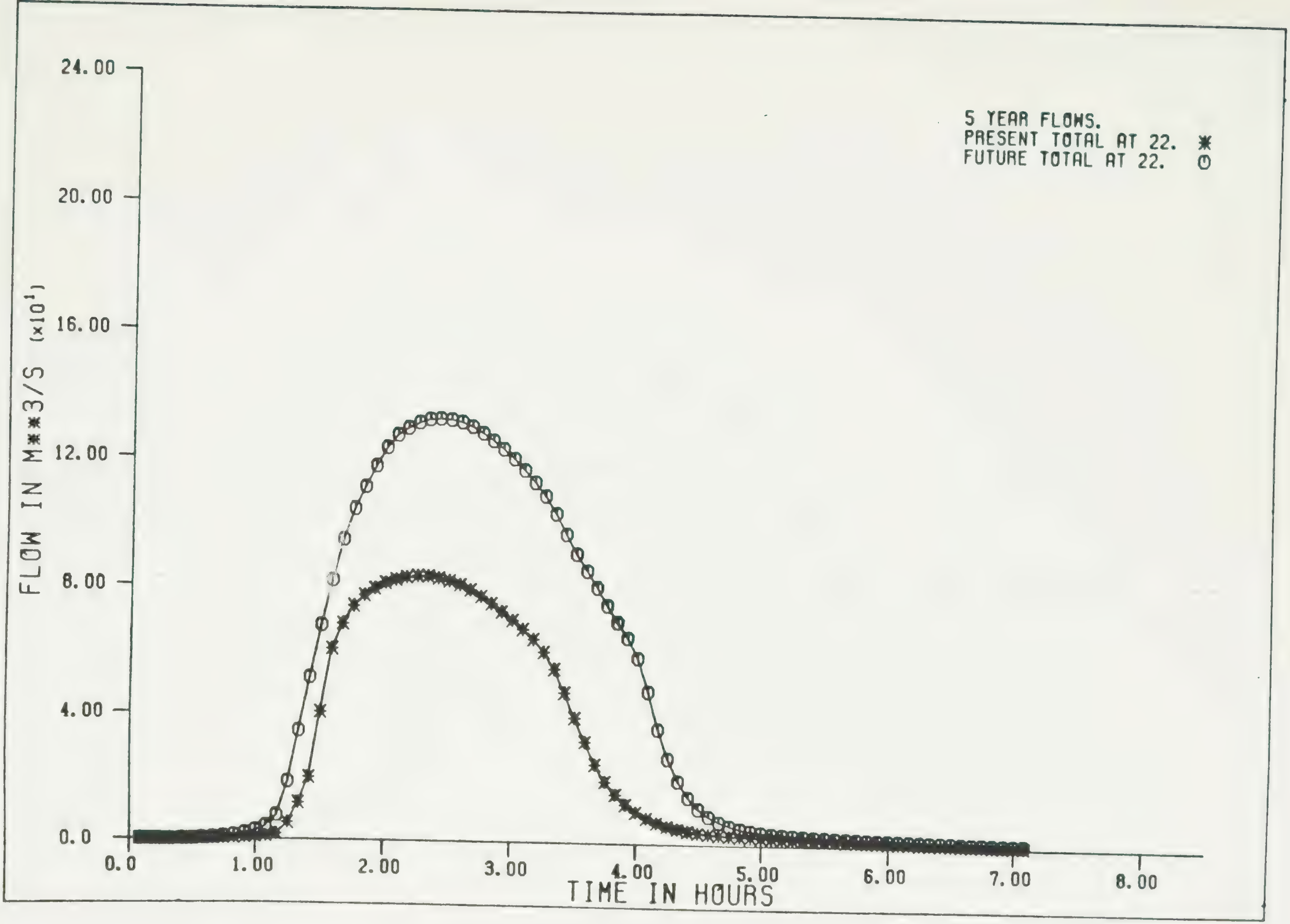


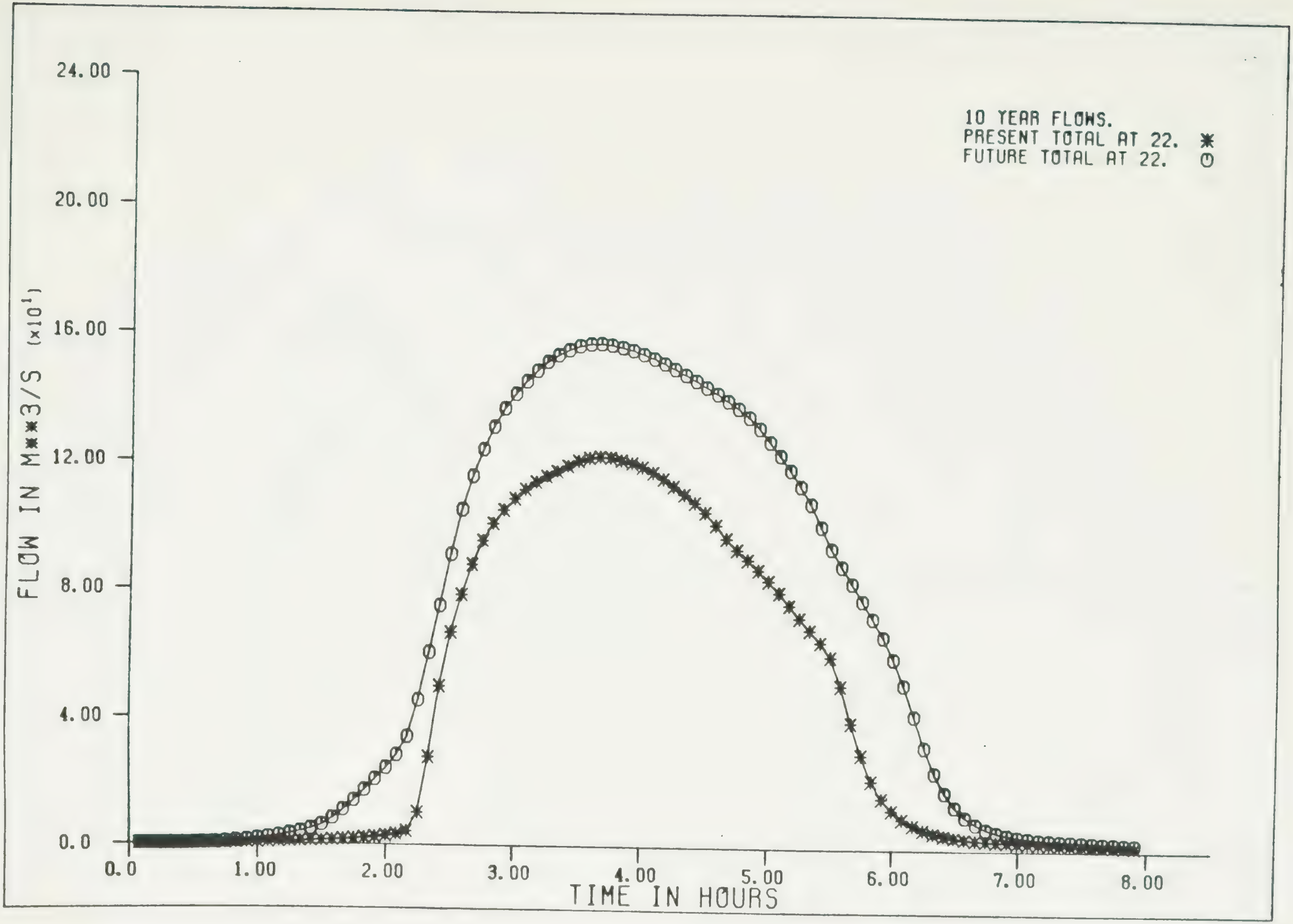
5 YEAR FLOWS.
PRESENT TOTAL AT 21. *
FUTURE TOTAL AT 21. O
FLOW IN M**3/S
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


10 YEAR FLOWS.
PRESENT TOTAL AT 21. *
FUTURE TOTAL AT 21. O
FLOW IN M**3/S
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

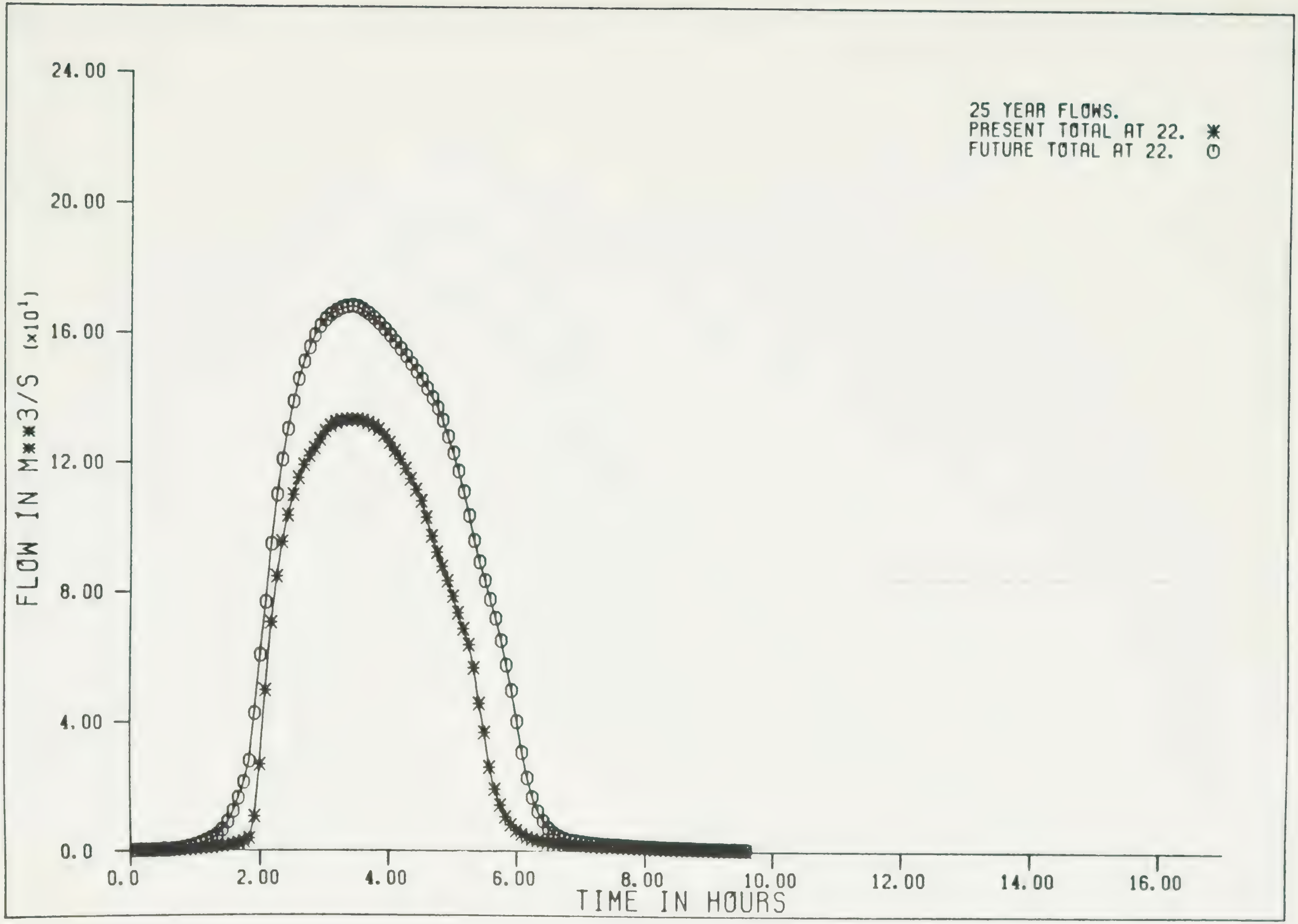

25 YEAR FLOWS.
PRESENT TOTAL AT 21. *
FUTURE TOTAL AT 21. O
FLOW IN M**3/S
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

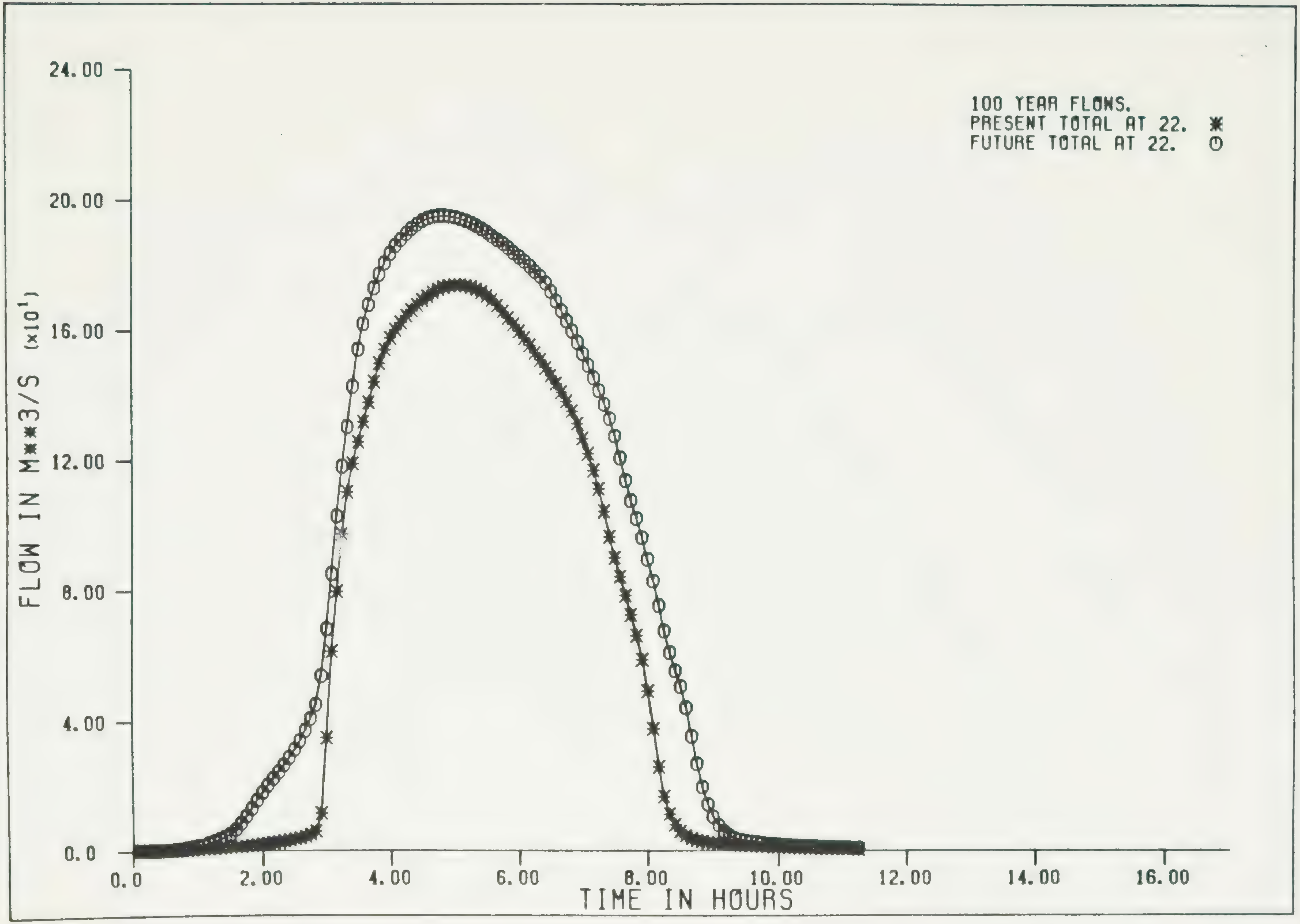

100 YEAR FLOWS.
PRESENT TOTAL AT 21. *
FUTURE TOTAL AT 21. O
FLOW IN M**3/S (x10[1])
TIME IN HOURS
6.00
5.00
4.00
3.00
2.00
1.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00


5 YEAR FLOWS.
PRESENT TOTAL AT 22. *
FUTURE TOTAL AT 22. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

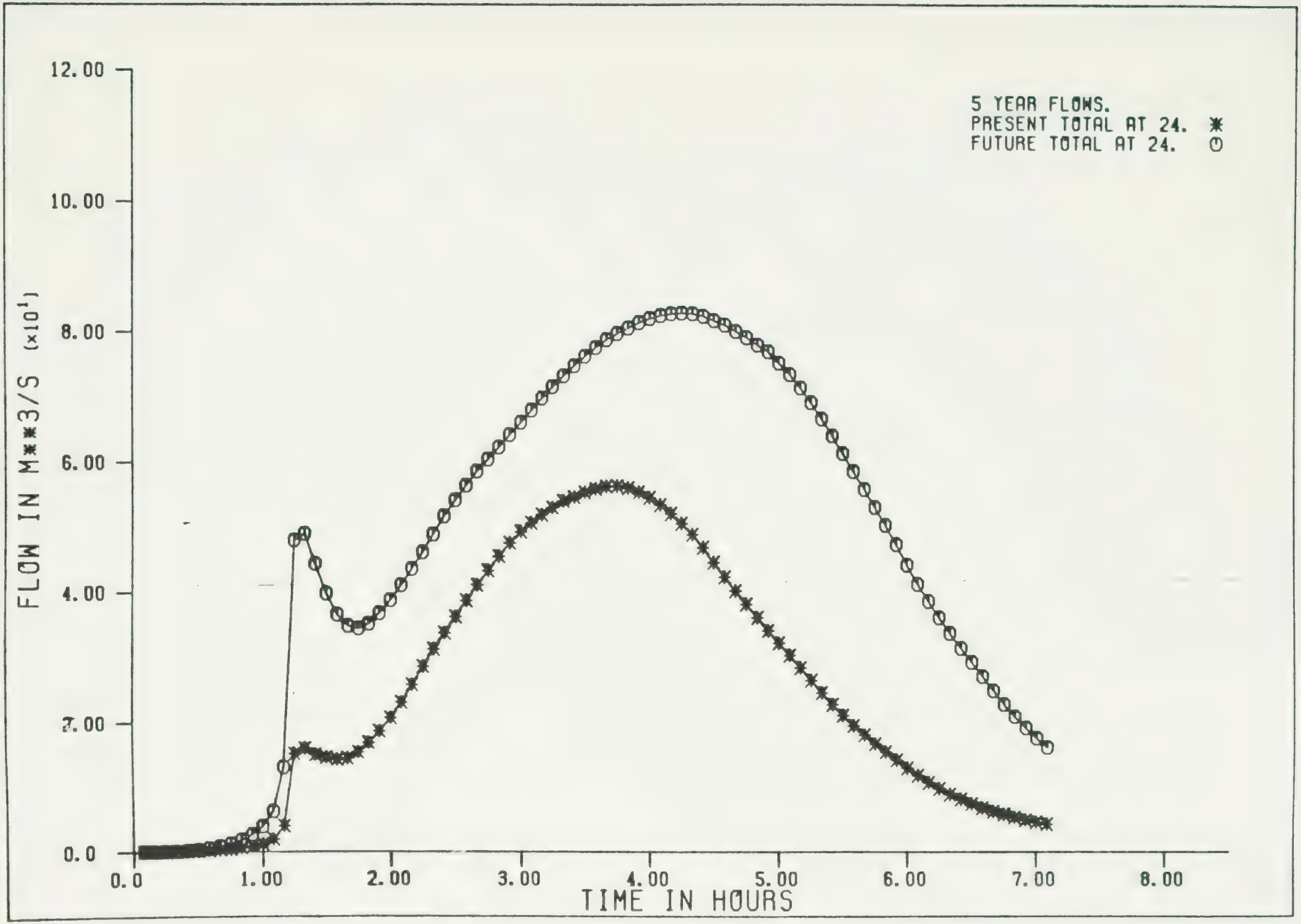


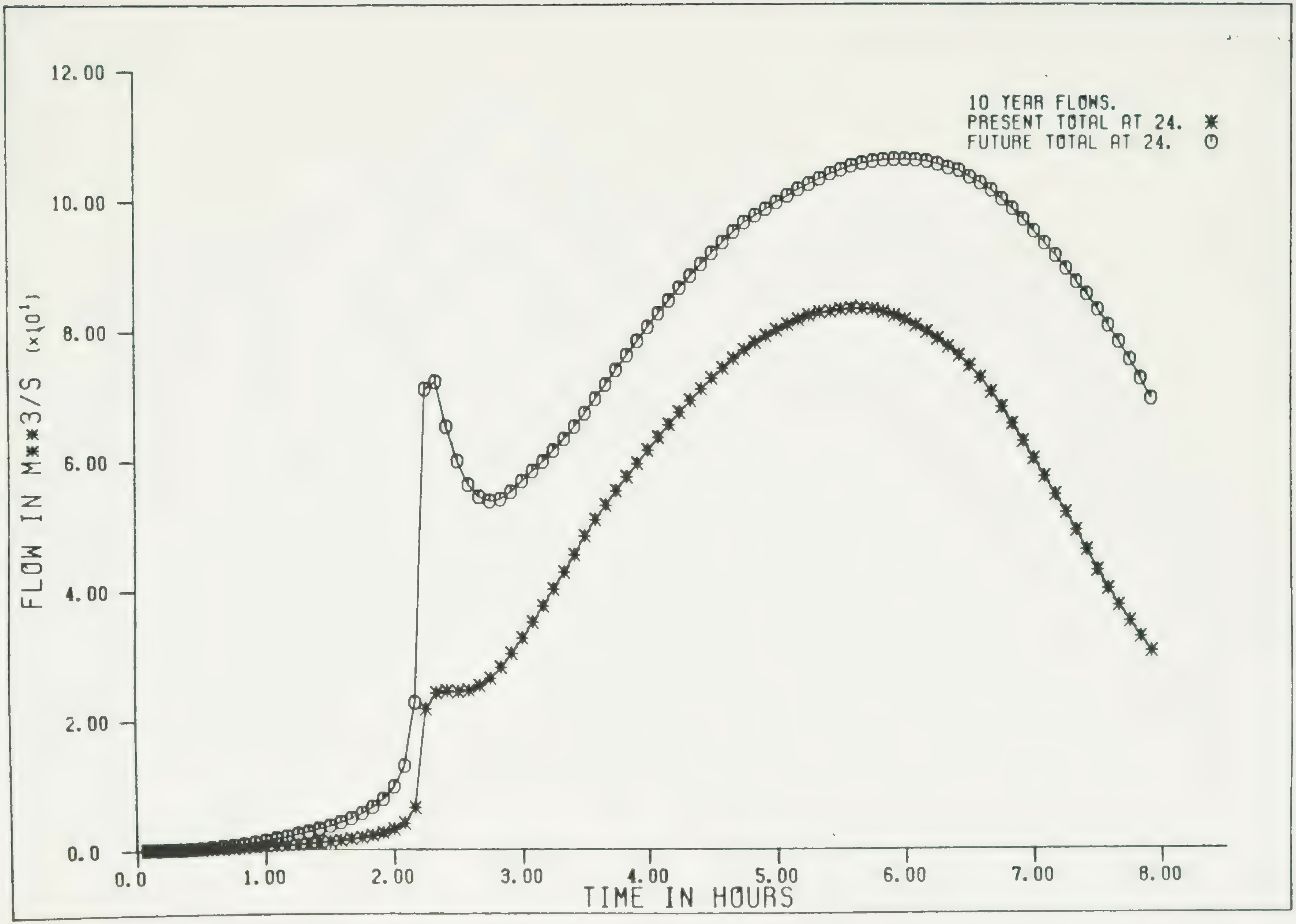
10 YEAR FLOWS.
PRESENT TOTAL AT 22. ✱
FUTURE TOTAL AT 22. ⊙
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

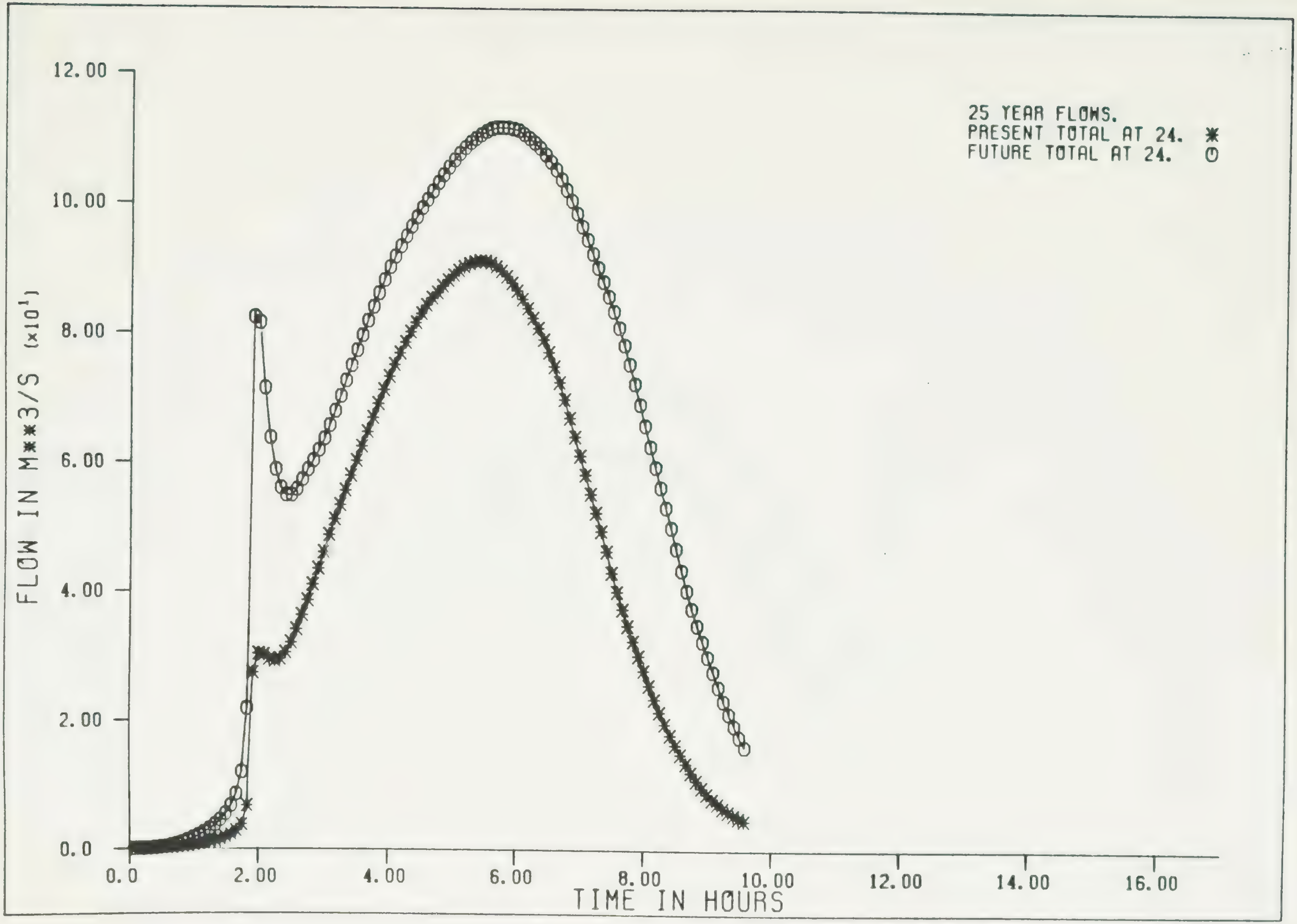

25 YEAR FLOWS.
PRESENT TOTAL AT 22. ✱
FUTURE TOTAL AT 22. ⊙
FLOW IN M**3/S (x10¹)
TIME IN HOURS
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00



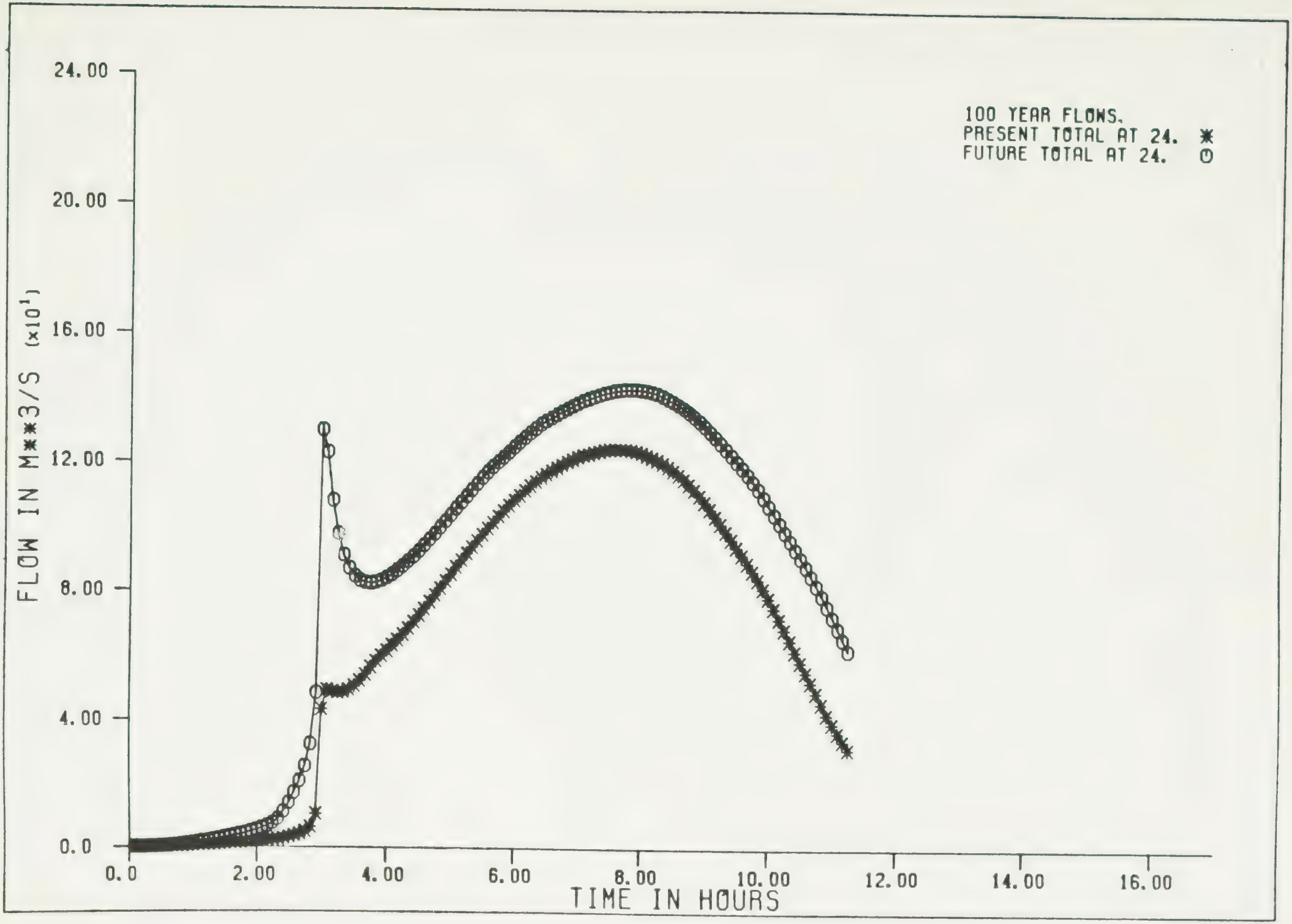
100 YEAR FLOWS.
PRESENT TOTAL AT 22. *
FUTURE TOTAL AT 22. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS


5 YEAR FLOWS.
PRESENT TOTAL AT 24. ✱
FUTURE TOTAL AT 24. O
12.00
10.00
8.00
6.00
4.00
2.00
0.0
FLOW IN M**3/S (x10¹)
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


10 YEAR FLOWS.
PRESENT TOTAL AT 24.
FUTURE TOTAL AT 24.
FLOW IN M**3/S (x10^1)
TIME IN HOURS
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
10.00
12.00



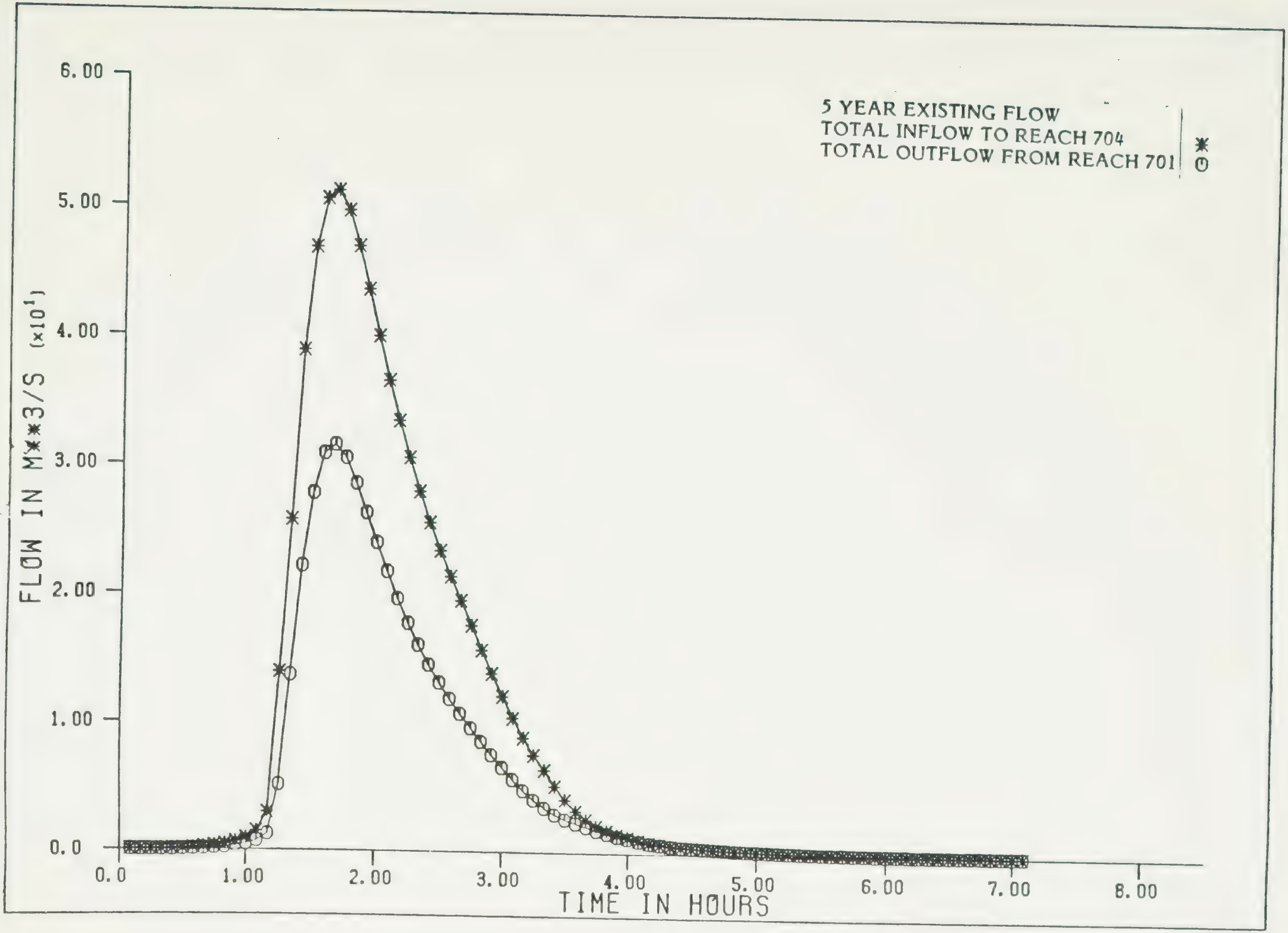
25 YEAR FLOWS.
PRESENT TOTAL AT 24. ✱
FUTURE TOTAL AT 24. O
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

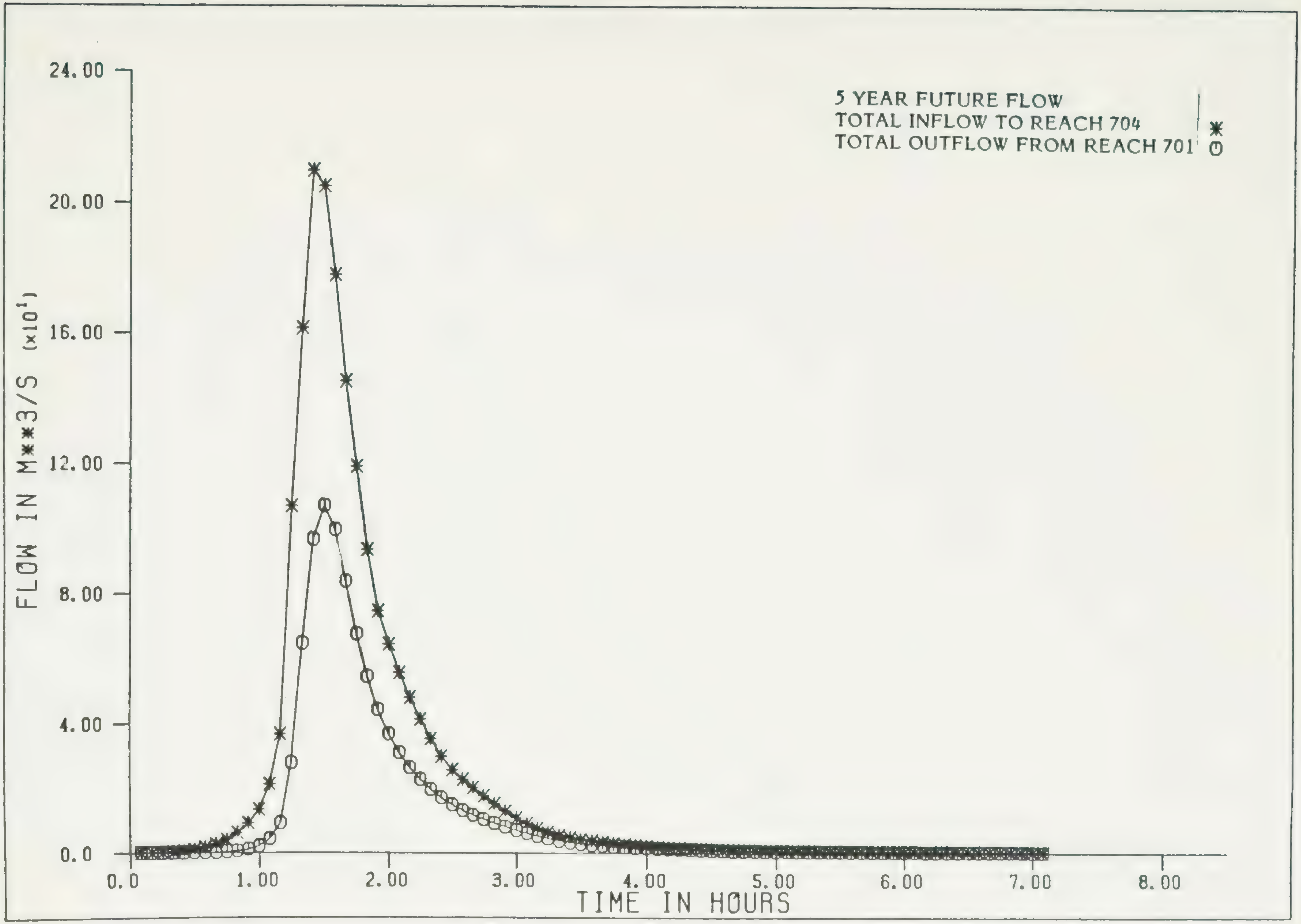


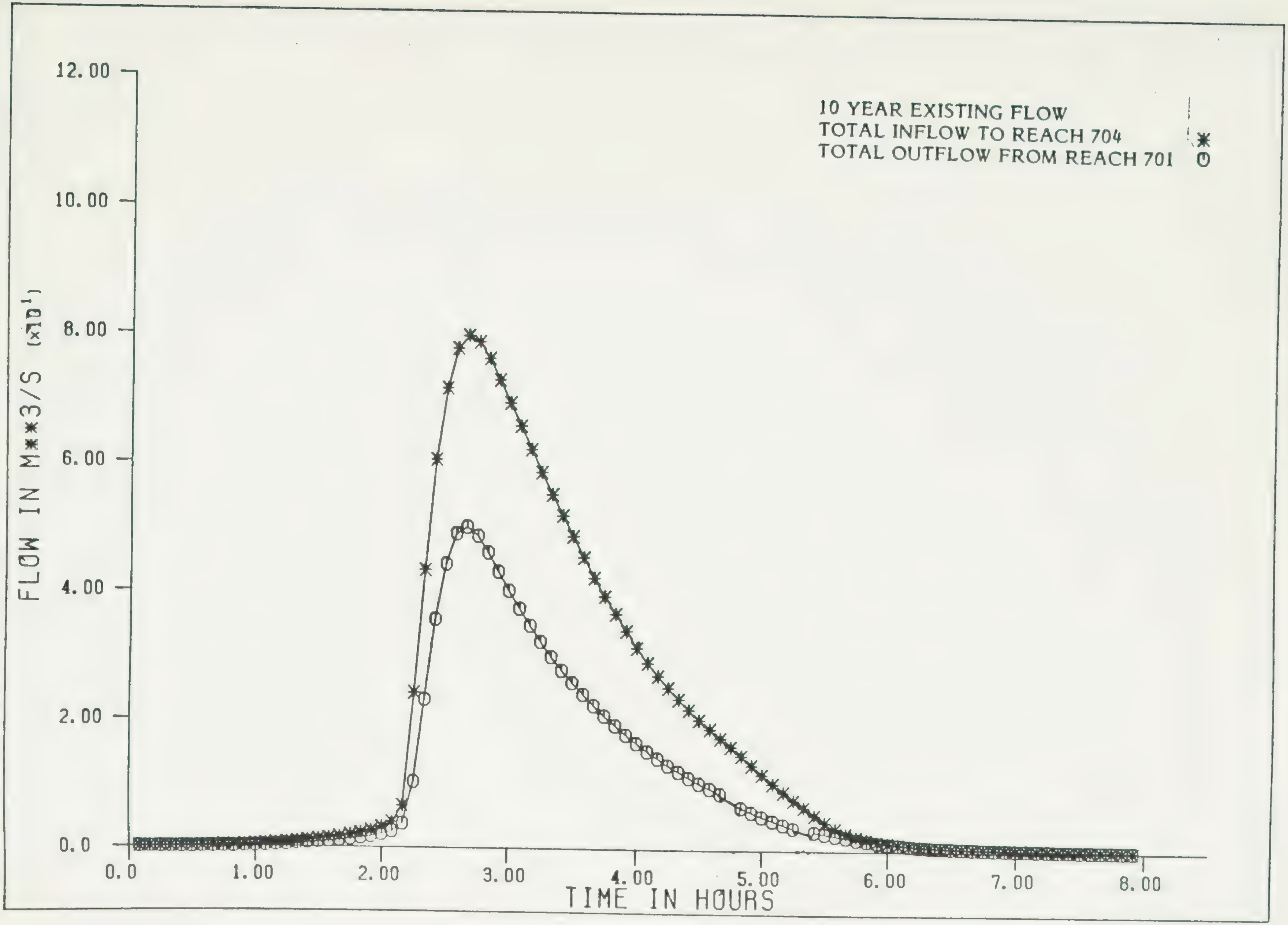
100 YEAR FLOWS.
PRESENT TOTAL AT 24. *
FUTURE TOTAL AT 24. O
FLOW IN M**3/S (x10^1)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

Hydrograph Set No. 2:

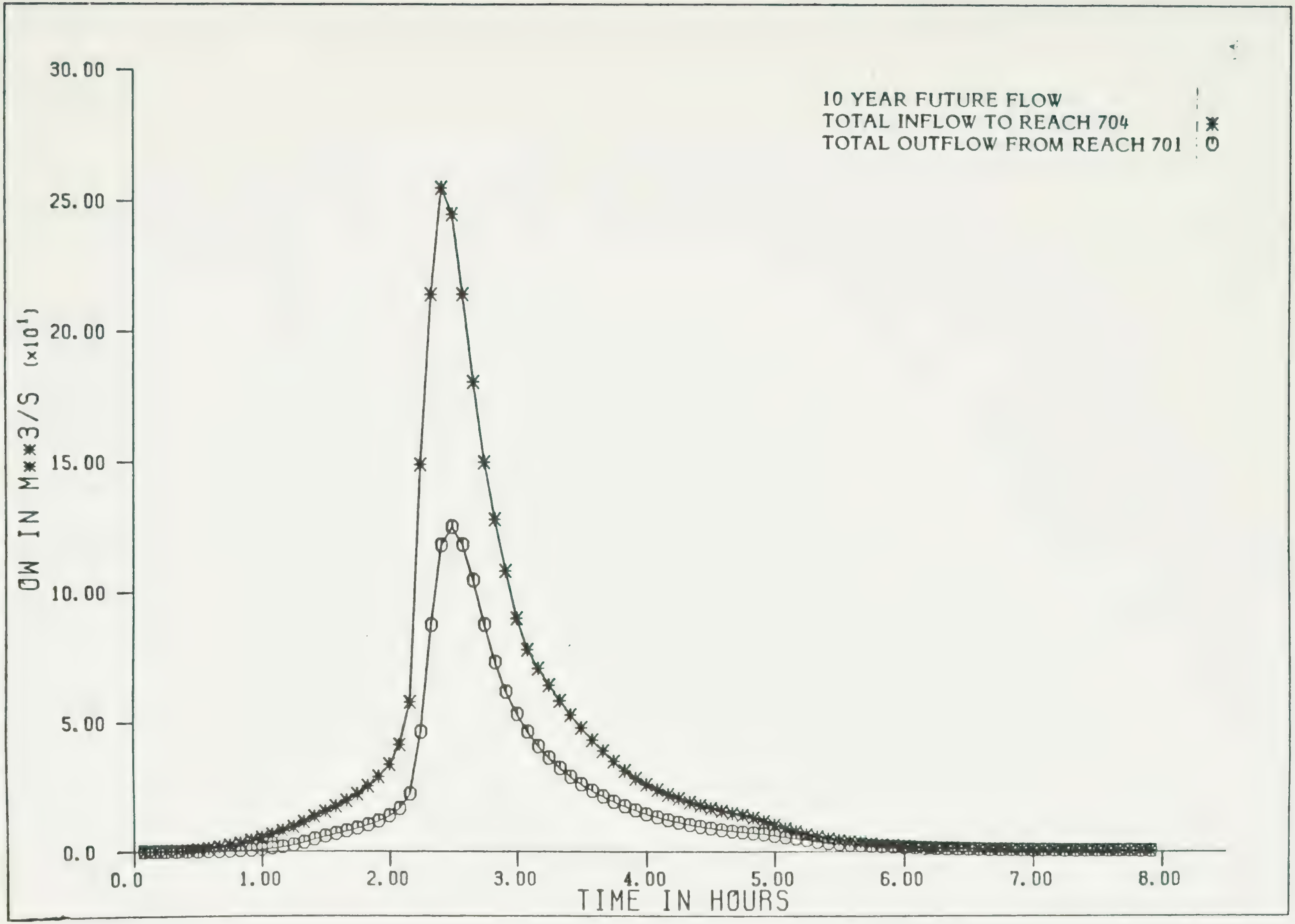
Importance of Various Branches of Various Junctions for Various Conditions

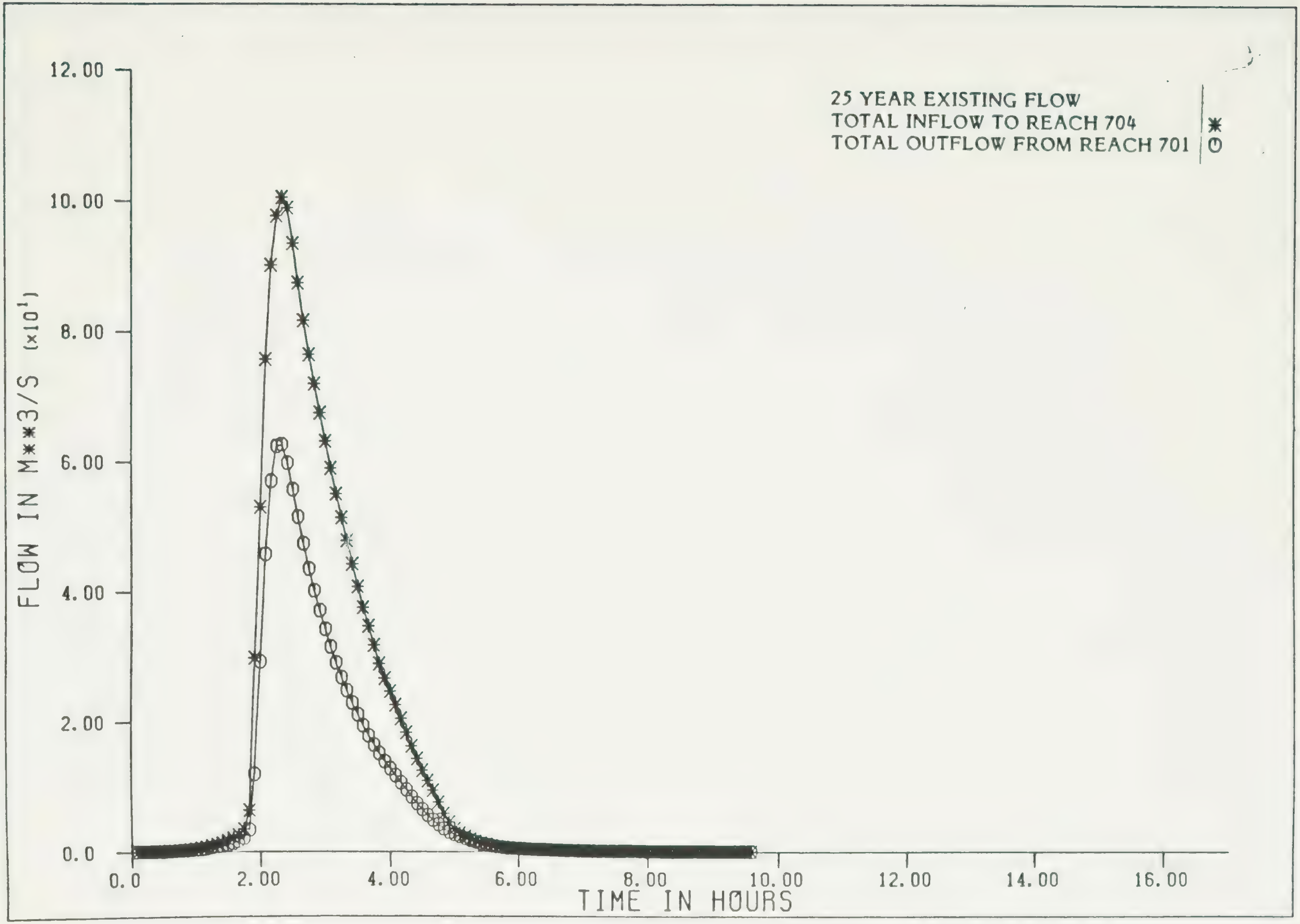

5 YEAR EXISTING FLOW
TOTAL INFLOW TO REACH 704
TOTAL OUTFLOW FROM REACH 701
FLOW IN M**3/S (x10¹)
TIME IN HOURS
6.00
5.00
4.00
3.00
2.00
1.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

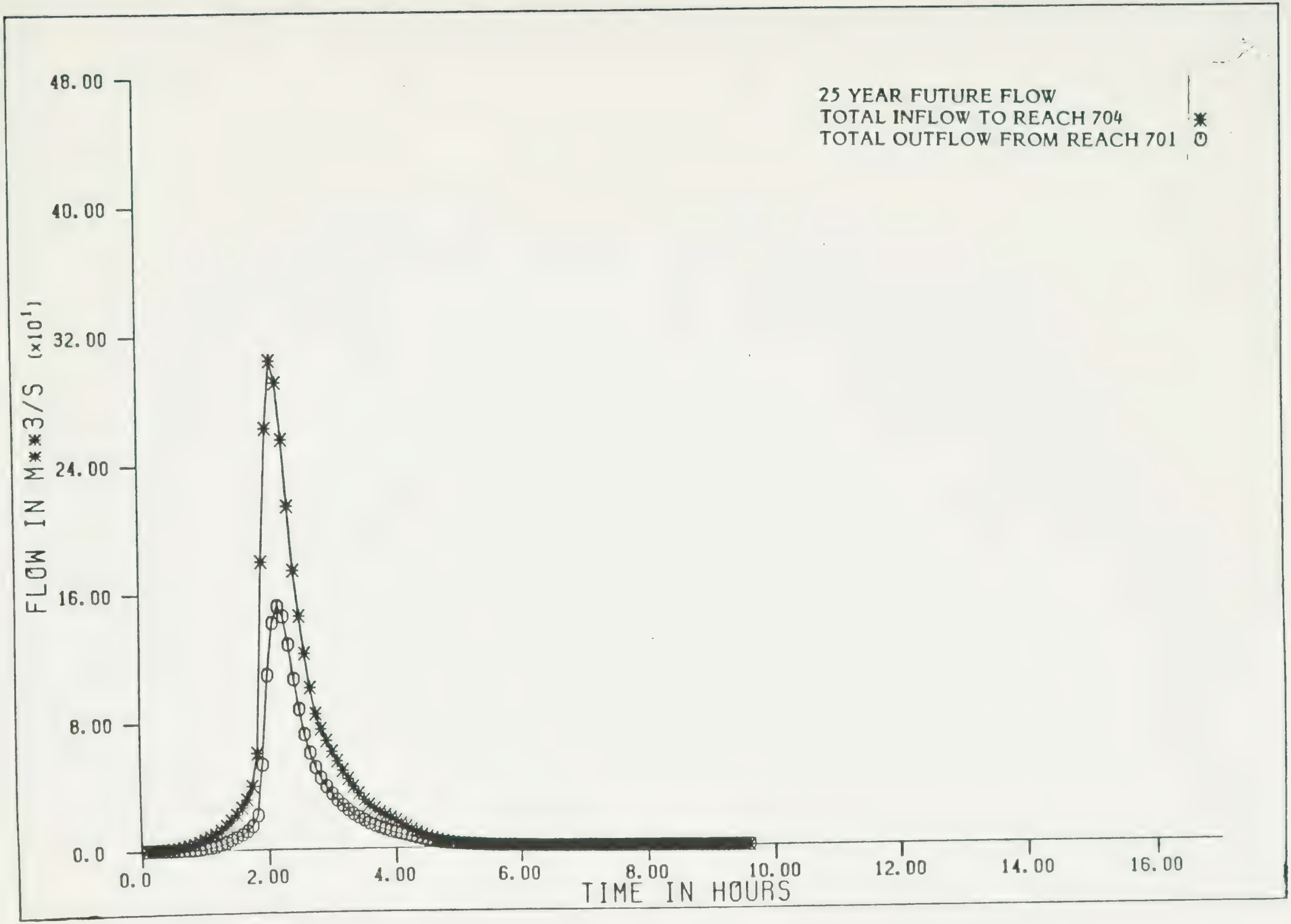

5 YEAR FUTURE FLOW
TOTAL INFLOW TO REACH 704 *
TOTAL OUTFLOW FROM REACH 701 O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

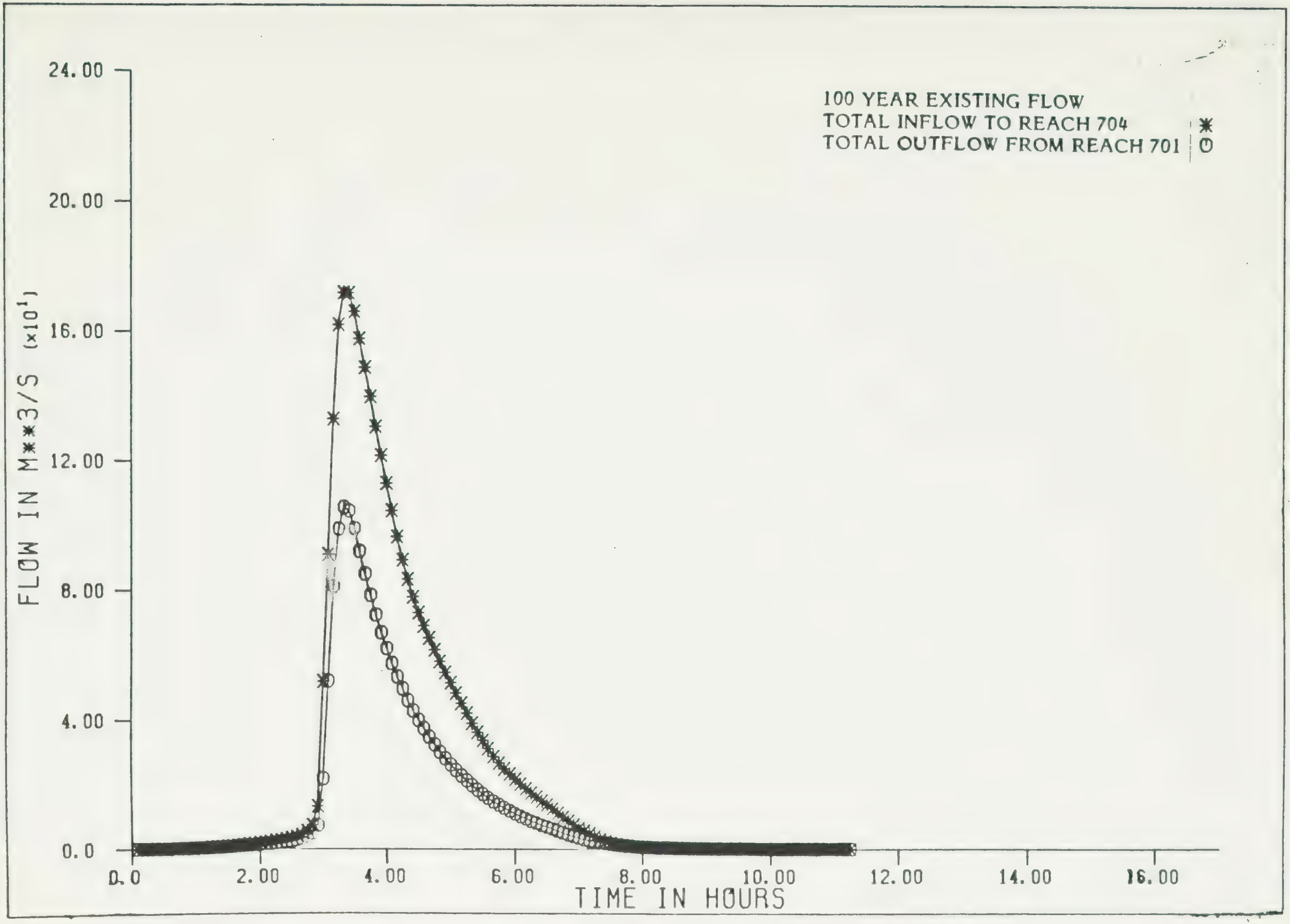


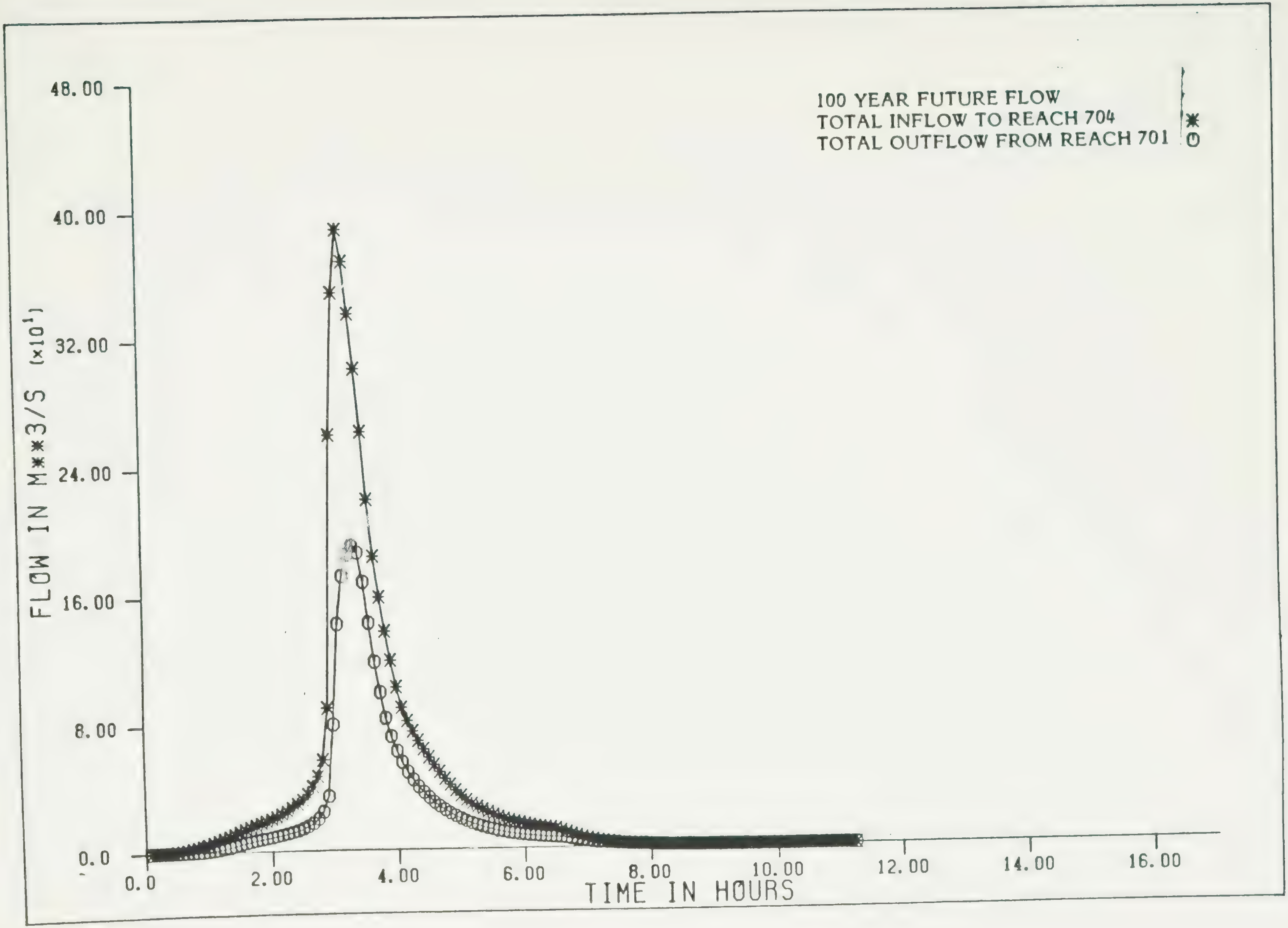
10 YEAR EXISTING FLOW
TOTAL INFLOW TO REACH 704
TOTAL OUTFLOW FROM REACH 701
FLOW IN M**3/S (x10^1)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

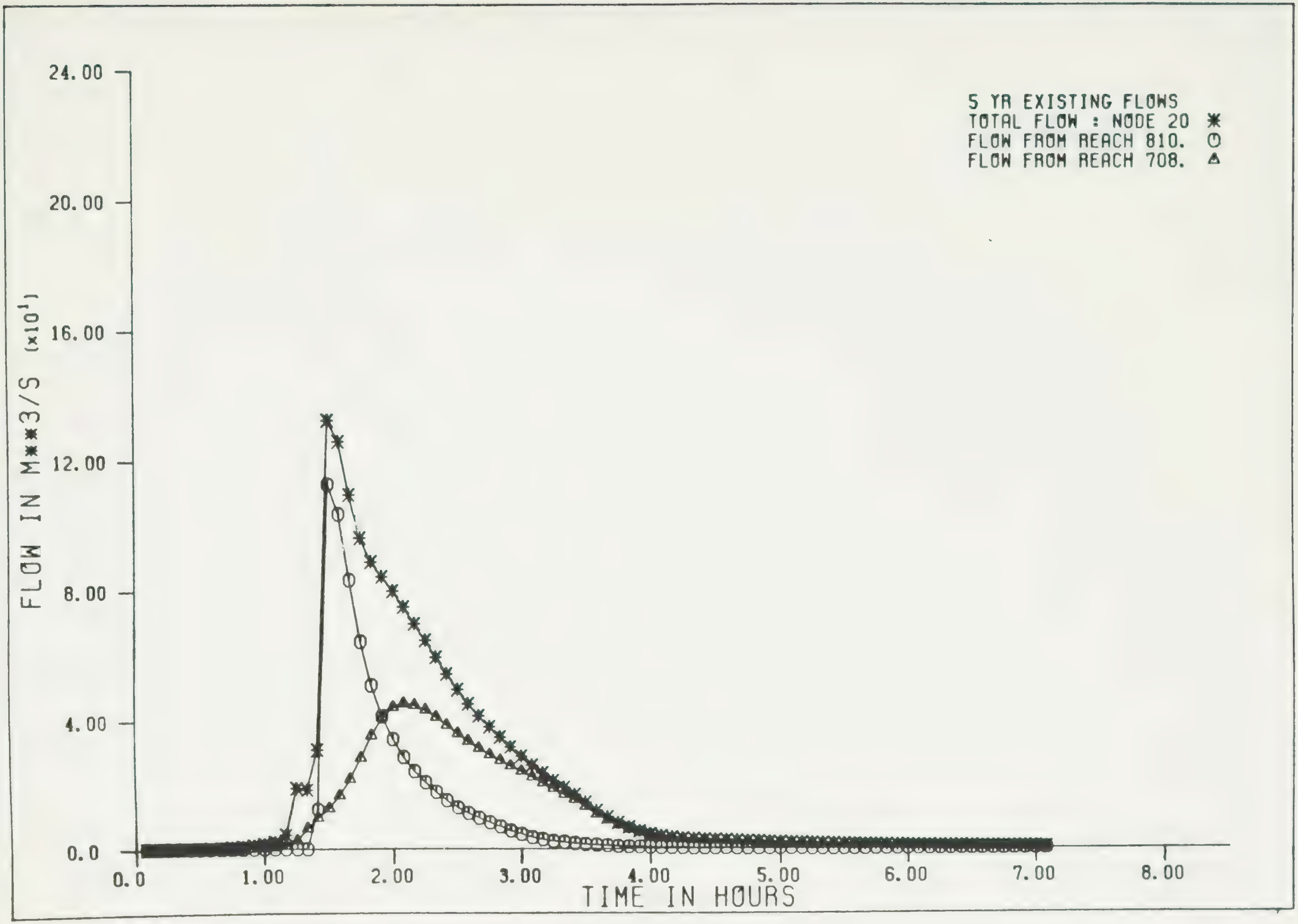

10 YEAR FUTURE FLOW
TOTAL INFLOW TO REACH 704
TOTAL OUTFLOW FROM REACH 701
QW IN M**3/S (x10¹)
30.00
25.00
20.00
15.00
10.00
5.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

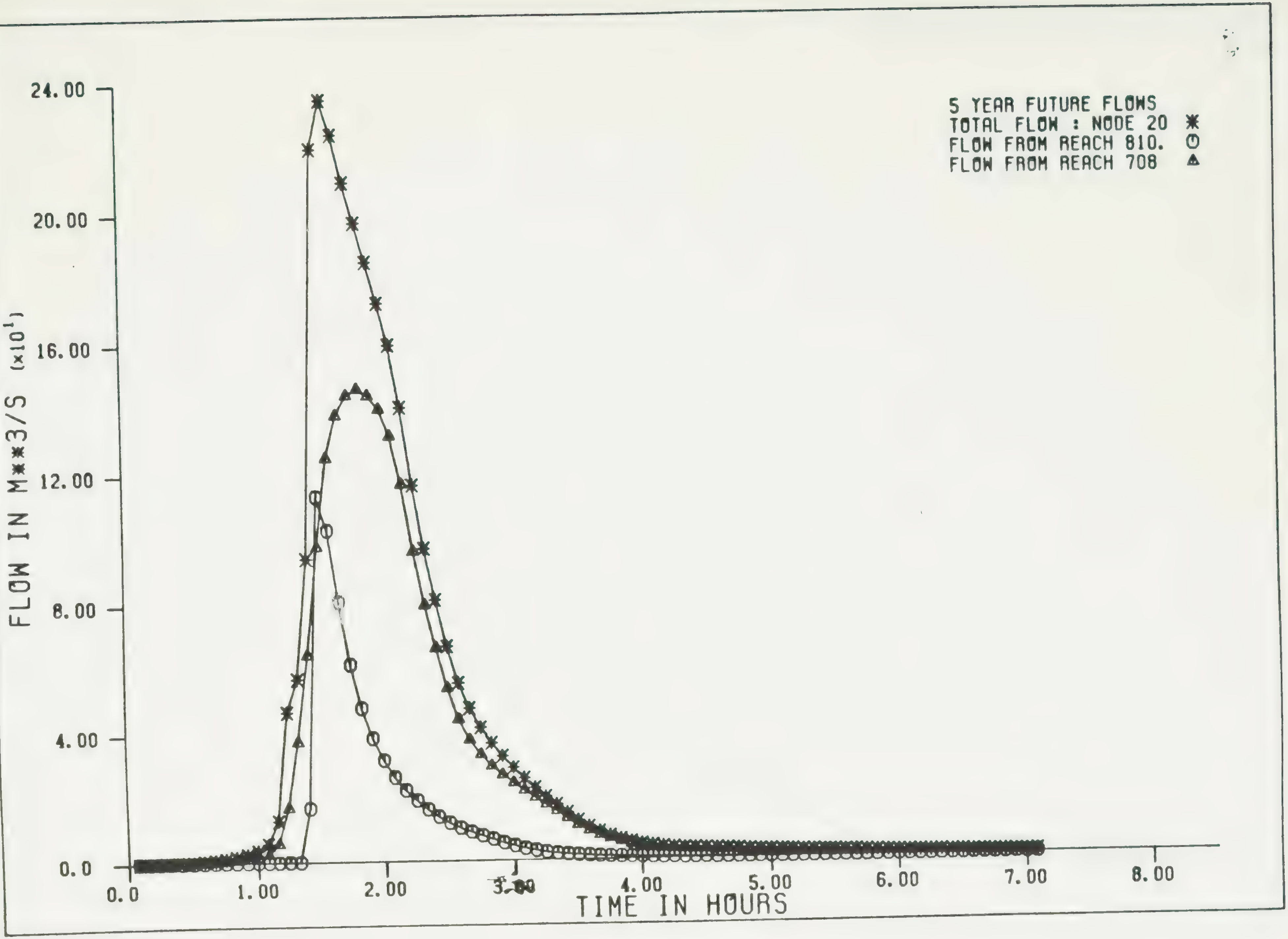

25 YEAR EXISTING FLOW
TOTAL INFLOW TO REACH 704
TOTAL OUTFLOW FROM REACH 701
12.00
10.00
8.00
6.00
4.00
2.00
0.0
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS


25 YEAR FUTURE FLOW
TOTAL INFLOW TO REACH 704
TOTAL OUTFLOW FROM REACH 701
FLOW IN M**3/S (x10^1)
TIME IN HOURS
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00

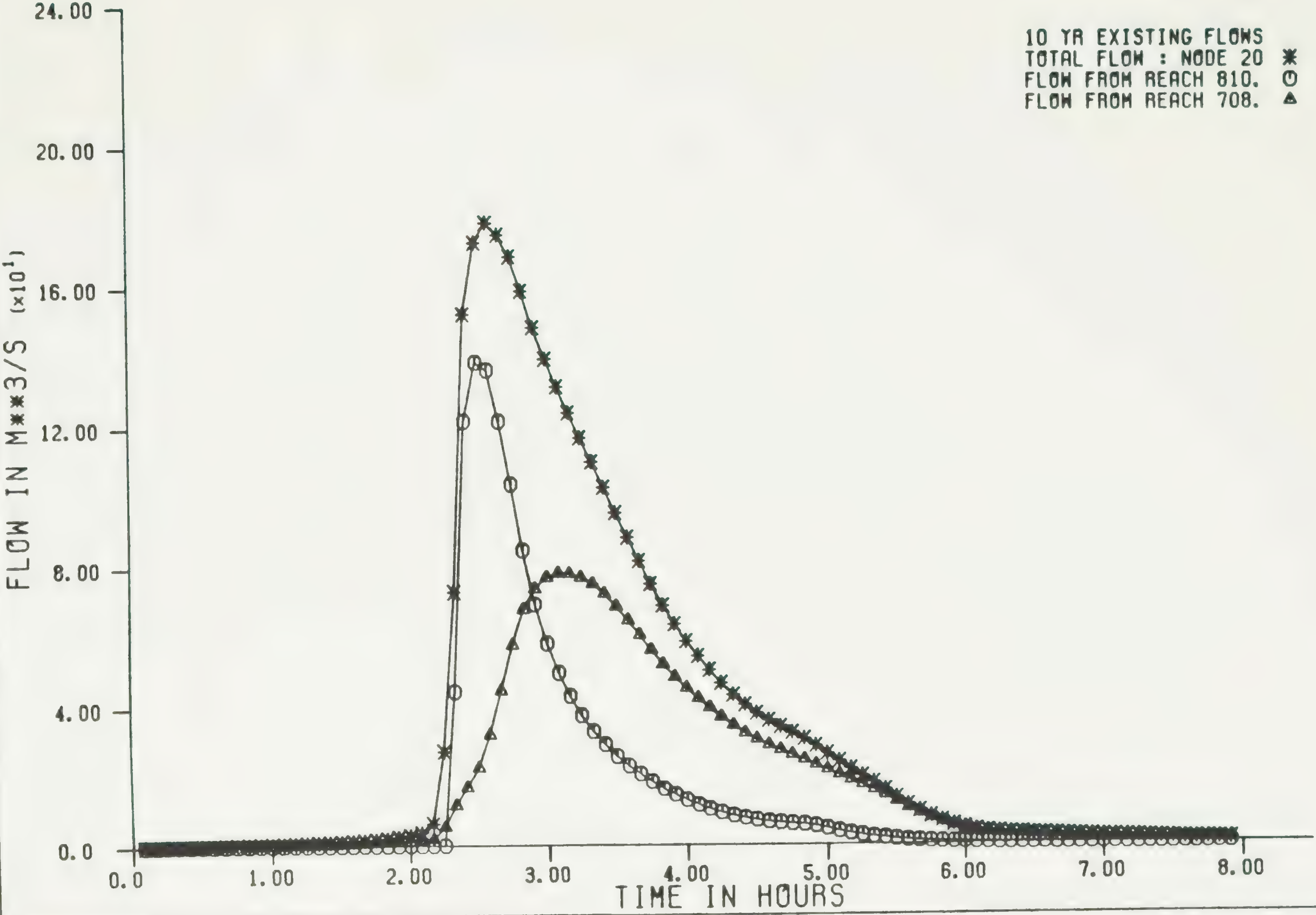

100 YEAR EXISTING FLOW
TOTAL INFLOW TO REACH 704 *
TOTAL OUTFLOW FROM REACH 701 O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

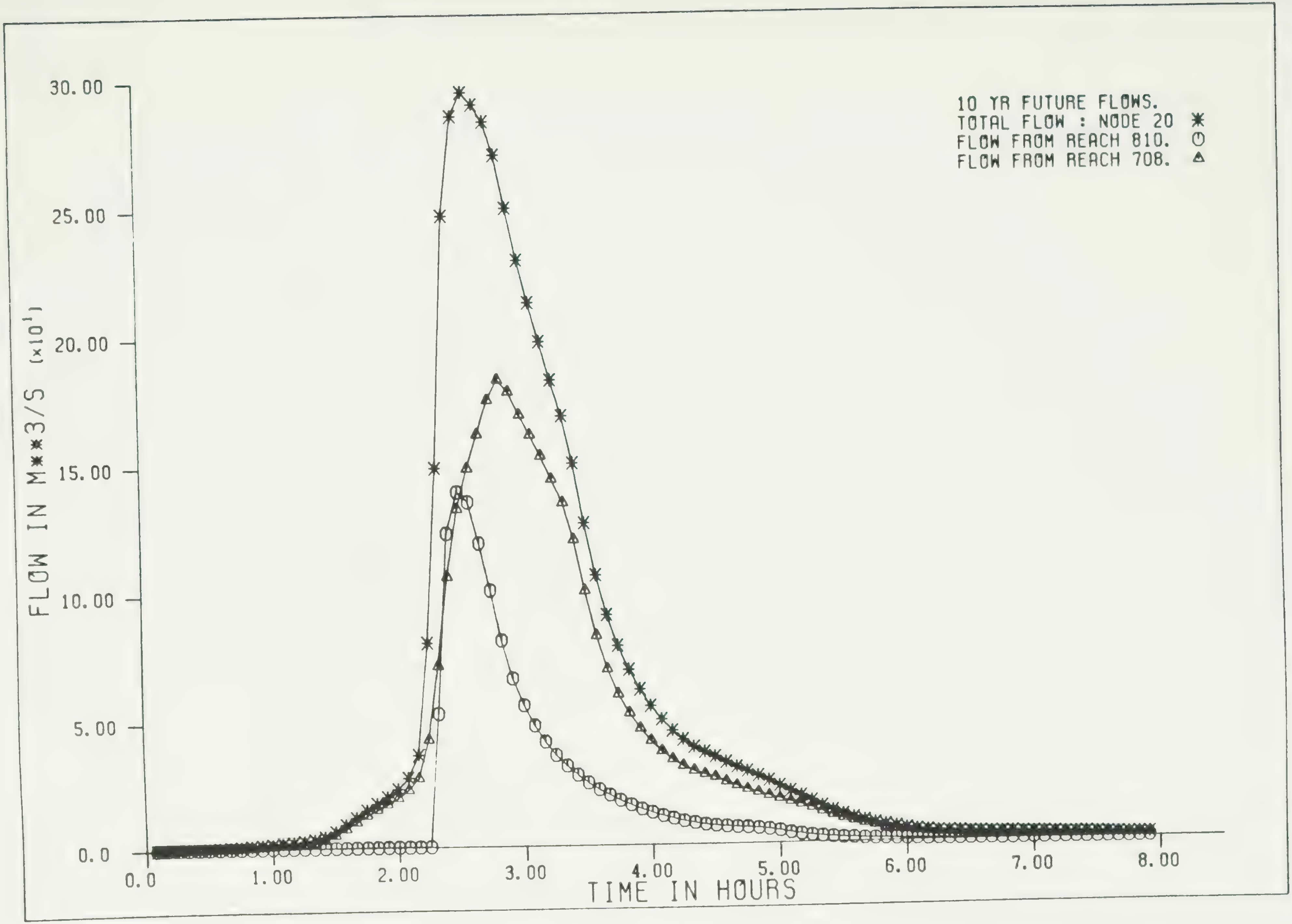

100 YEAR FUTURE FLOW
TOTAL INFLOW TO REACH 704
TOTAL OUTFLOW FROM REACH 701
48.00
40.00
32.00
24.00
16.00
8.00
0.0
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

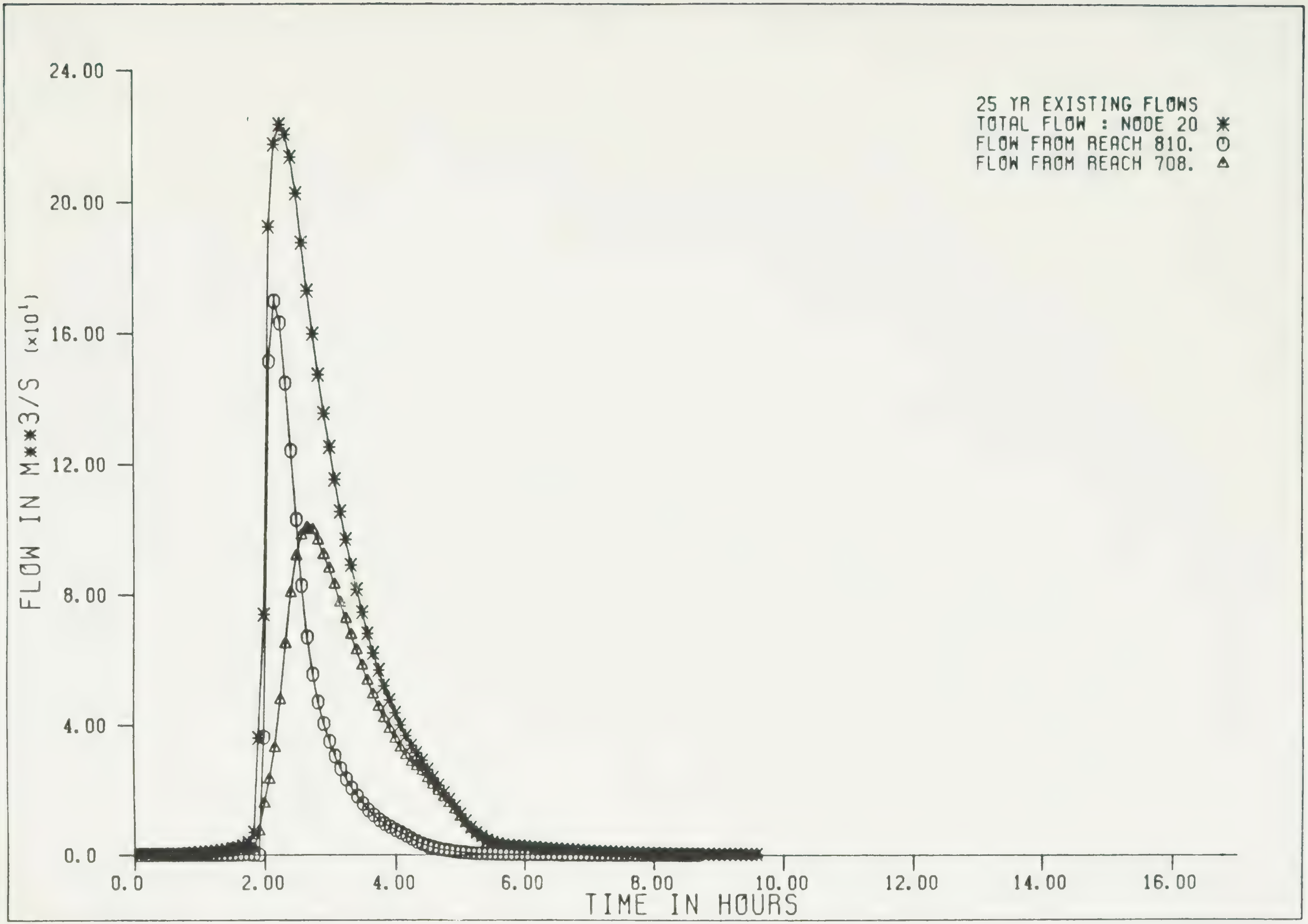

5 YR EXISTING FLOWS
TOTAL FLOW : NODE 20 ✱
FLOW FROM REACH 810. O
FLOW FROM REACH 708. △
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

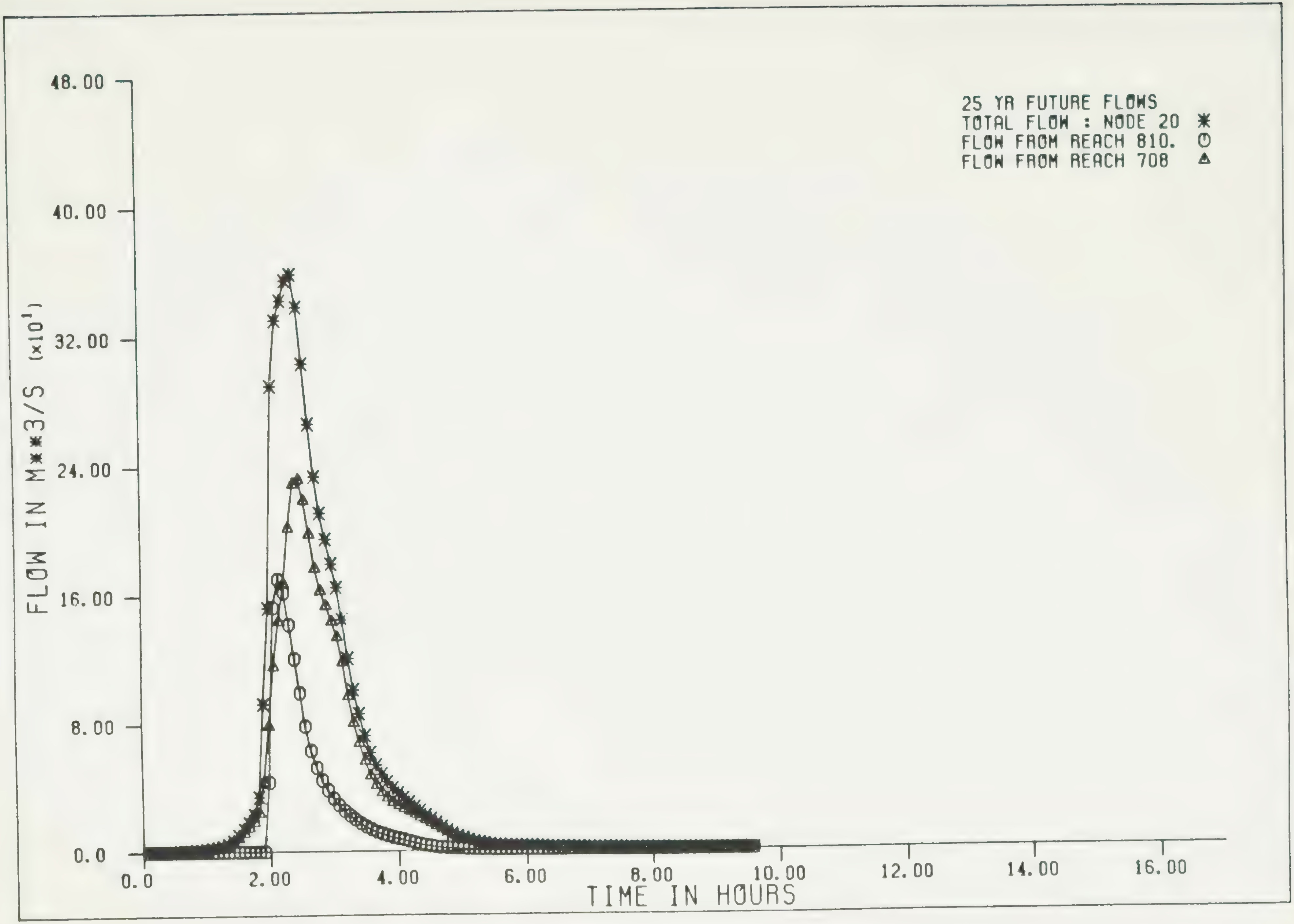


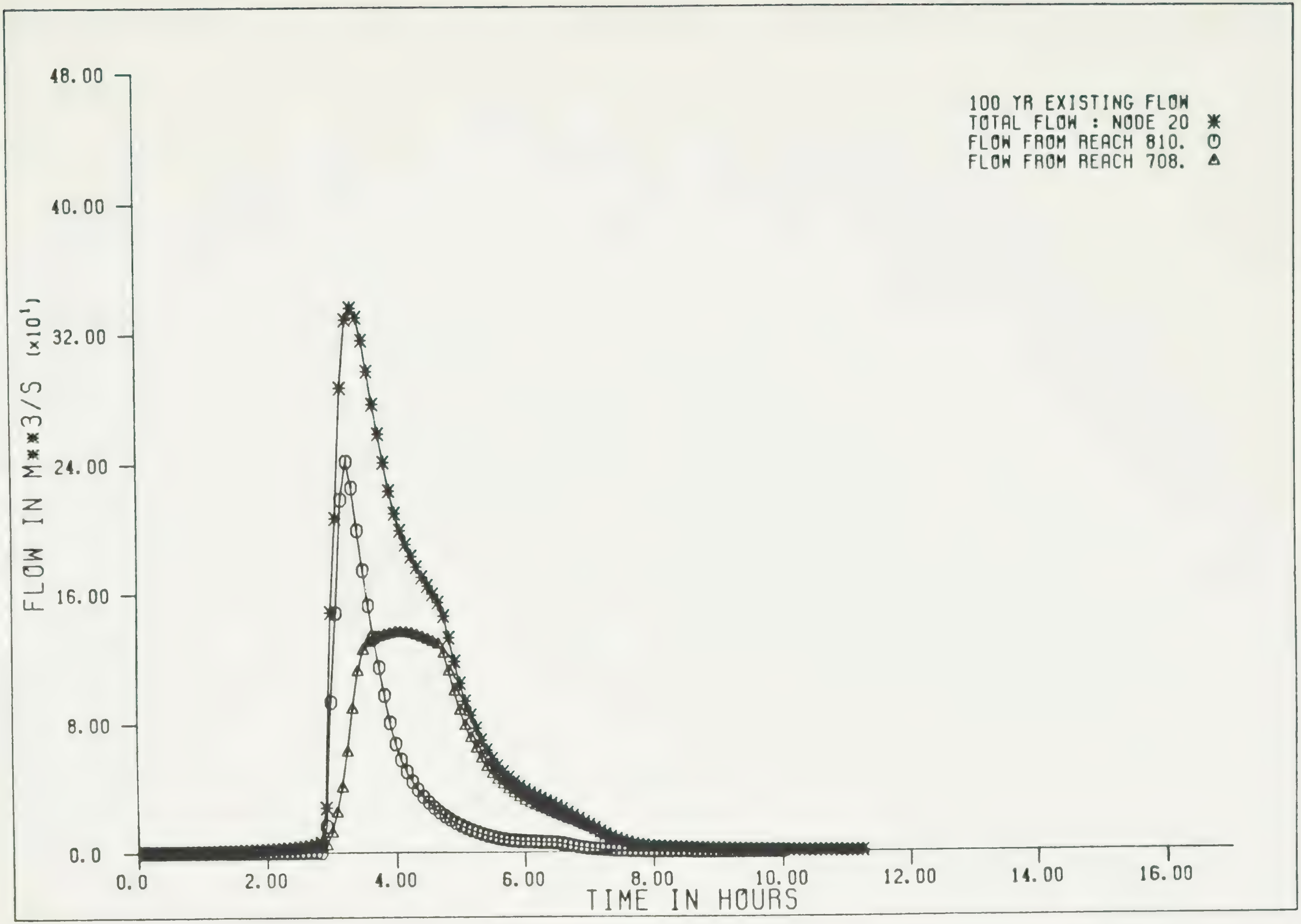
5 YEAR FUTURE FLOWS
TOTAL FLOW : NODE 20
FLOW FROM REACH 810.
FLOW FROM REACH 708
FLOW IN M**3/S (x10^1)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

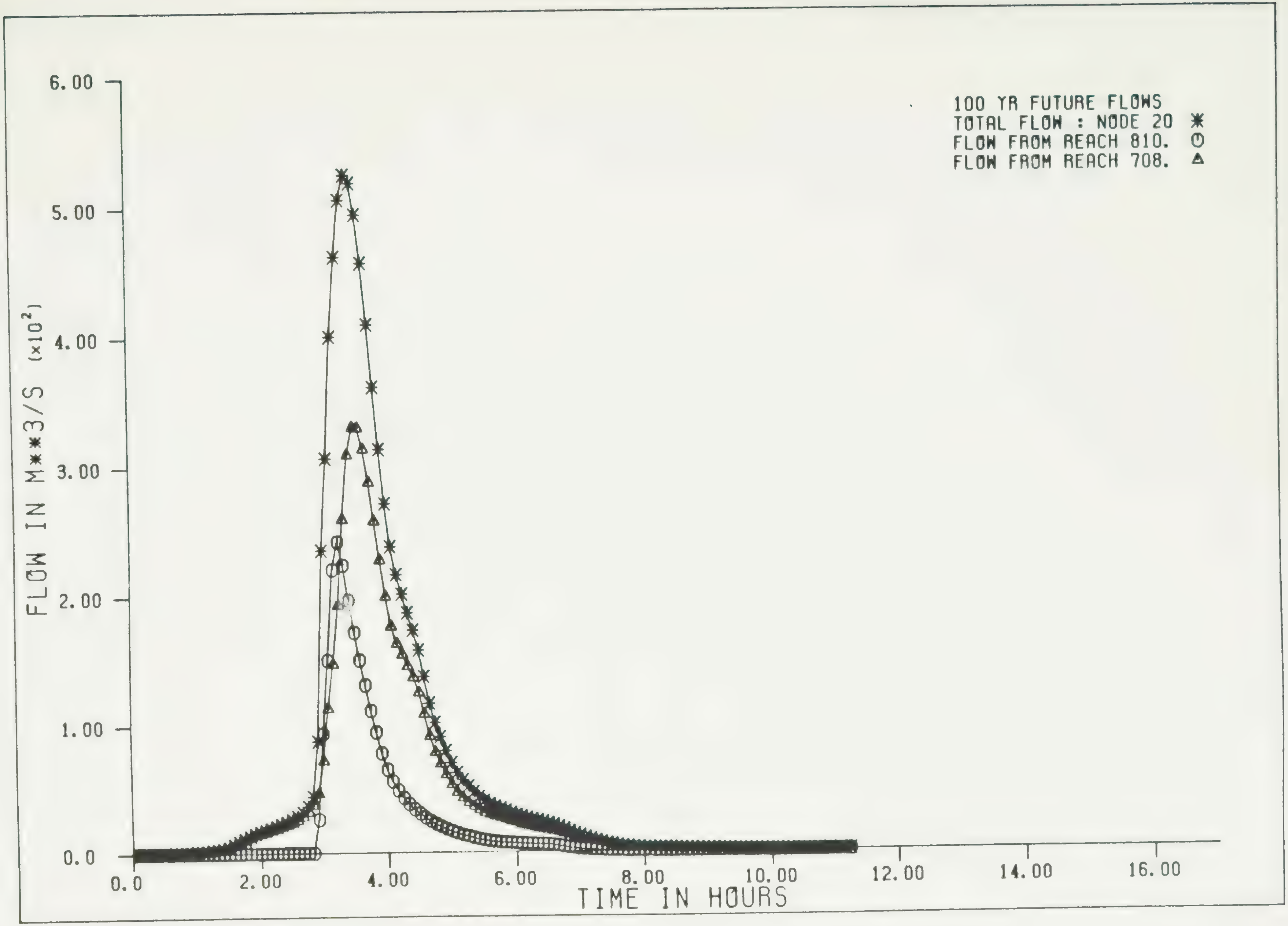

10 YR EXISTING FLOWS
TOTAL FLOW : NODE 20
FLOW FROM REACH 810.
FLOW FROM REACH 708.
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

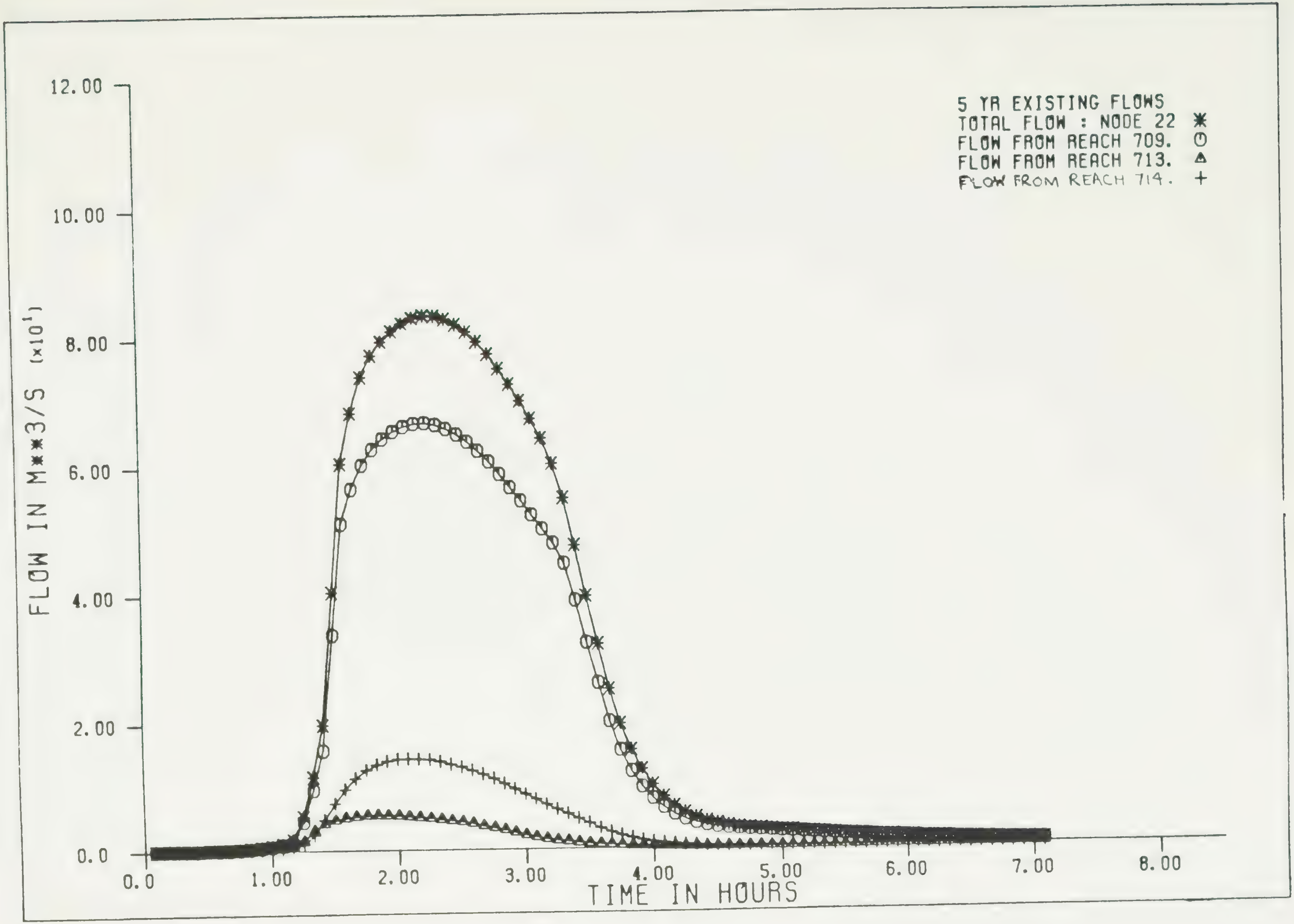

10 YR FUTURE FLOWS.
TOTAL FLOW : NODE 20 *
FLOW FROM REACH 810. O
FLOW FROM REACH 708. Δ
FLOW IN M**3/S (x10[1])
TIME IN HOURS
30.00
25.00
20.00
15.00
10.00
5.00
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00


25 YR EXISTING FLOWS
TOTAL FLOW : NODE 20
FLOW FROM REACH 810.
FLOW FROM REACH 708.
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

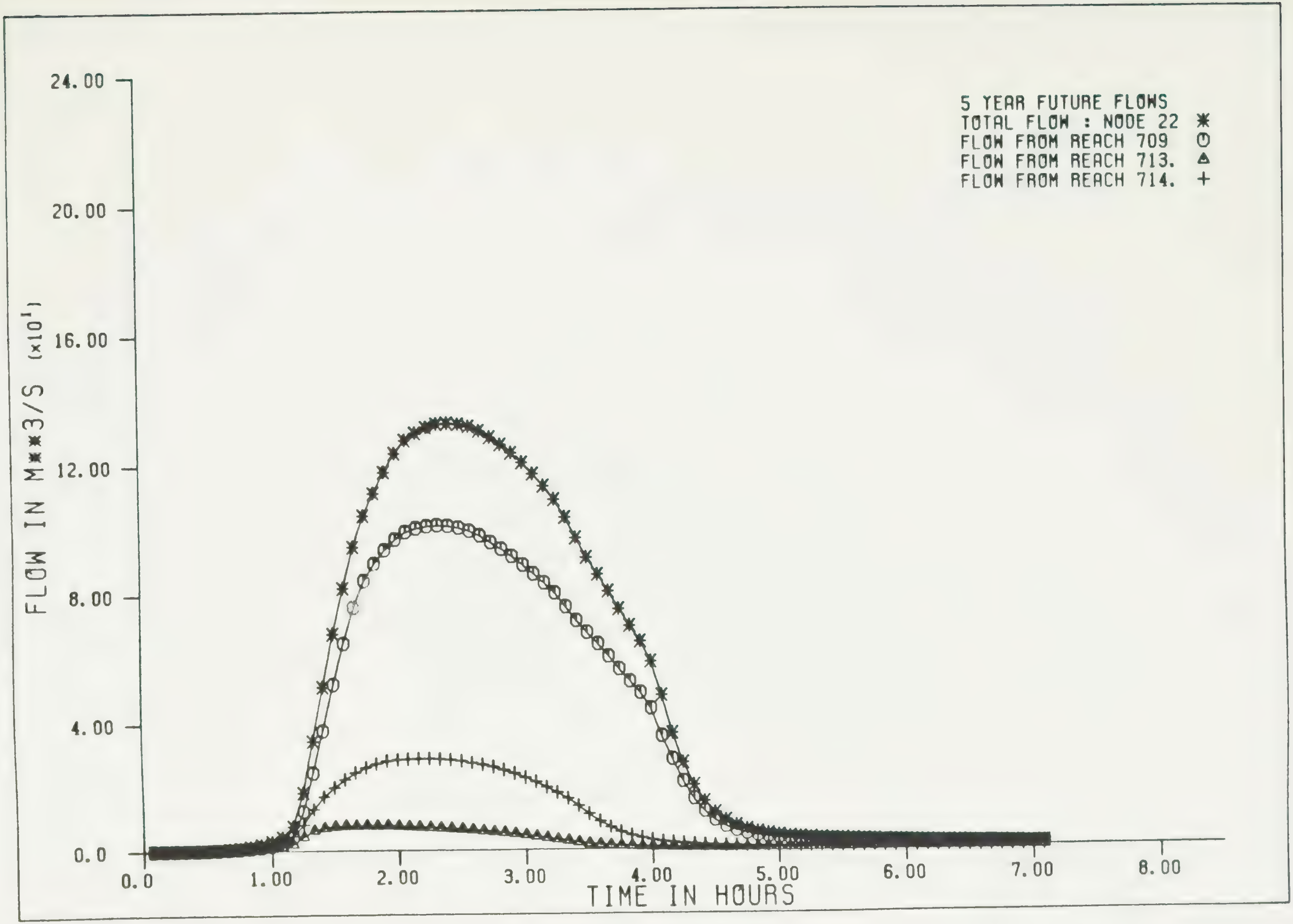

25 YR FUTURE FLOWS
TOTAL FLOW : NODE 20 ✱
FLOW FROM REACH 810. O
FLOW FROM REACH 708 Δ
48.00
40.00
32.00
24.00
16.00
8.00
0.0
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

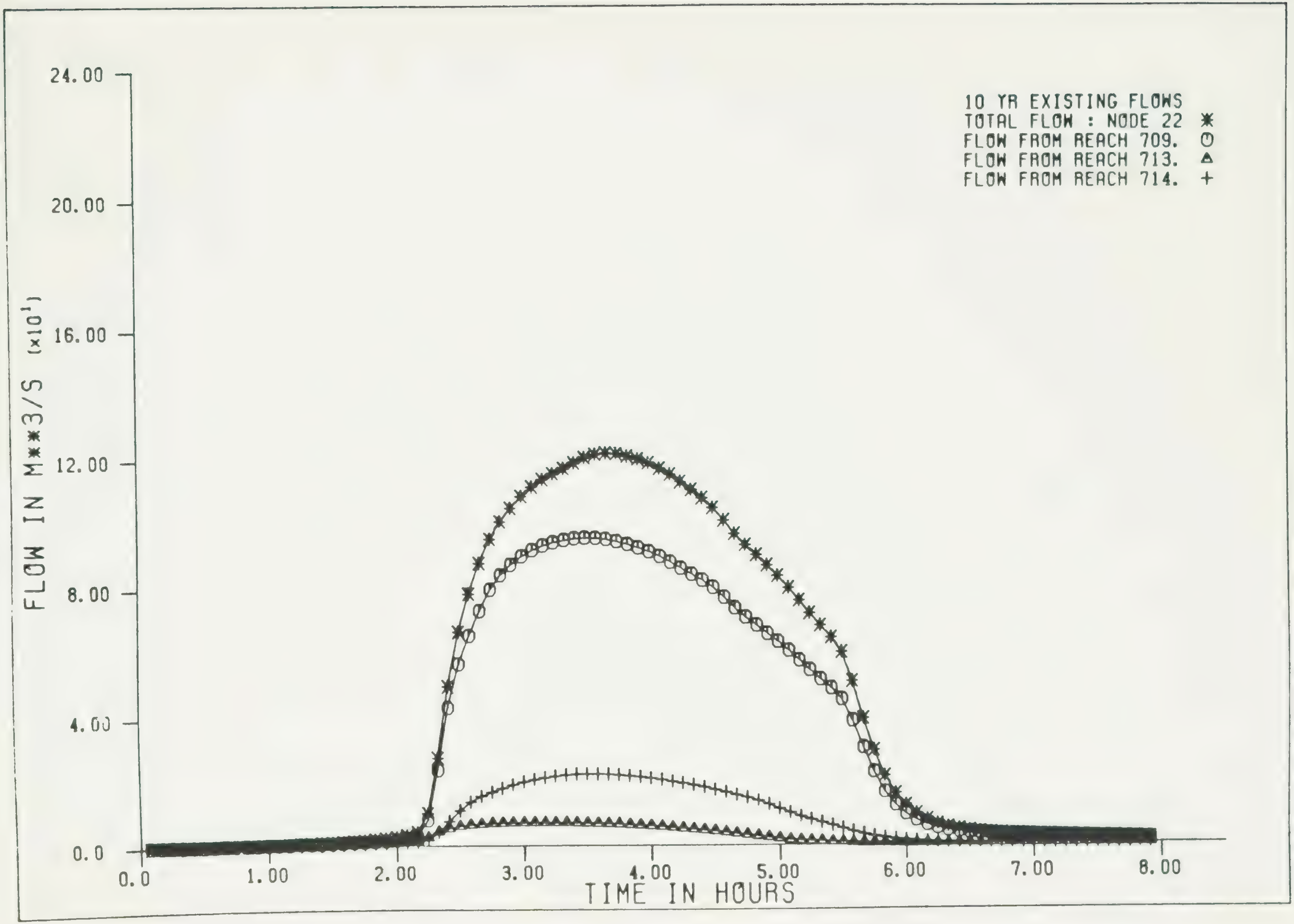

100 YR EXISTING FLOW
TOTAL FLOW : NODE 20
FLOW FROM REACH 810.
FLOW FROM REACH 708.
FLOW IN M**3/S (x10¹)
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS


100 YR FUTURE FLOWS
TOTAL FLOW : NODE 20 ✱
FLOW FROM REACH 810. O
FLOW FROM REACH 708. Δ
FLOW IN M**3/S (x10²)
TIME IN HOURS
6.00
5.00
4.00
3.00
2.00
1.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00

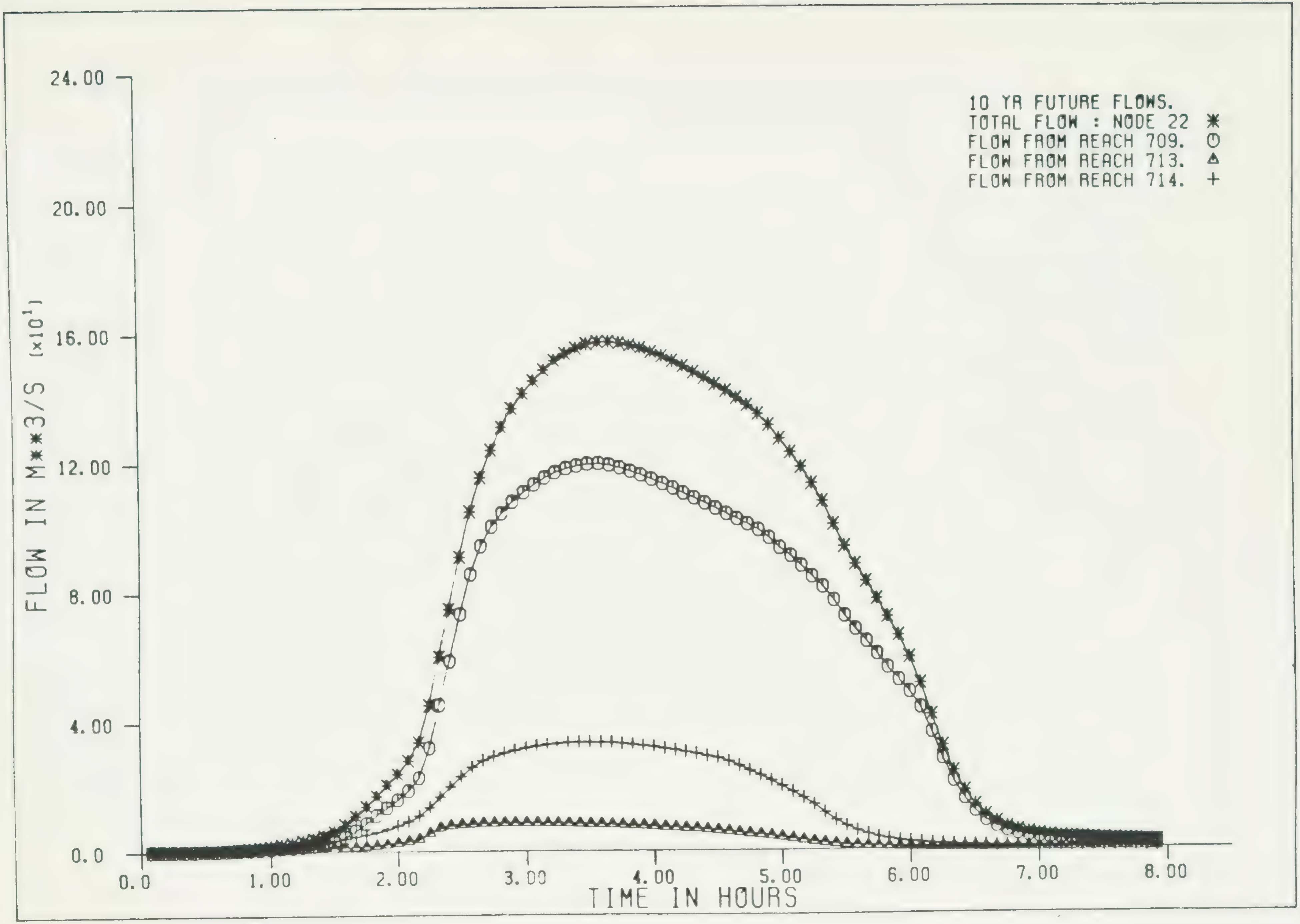


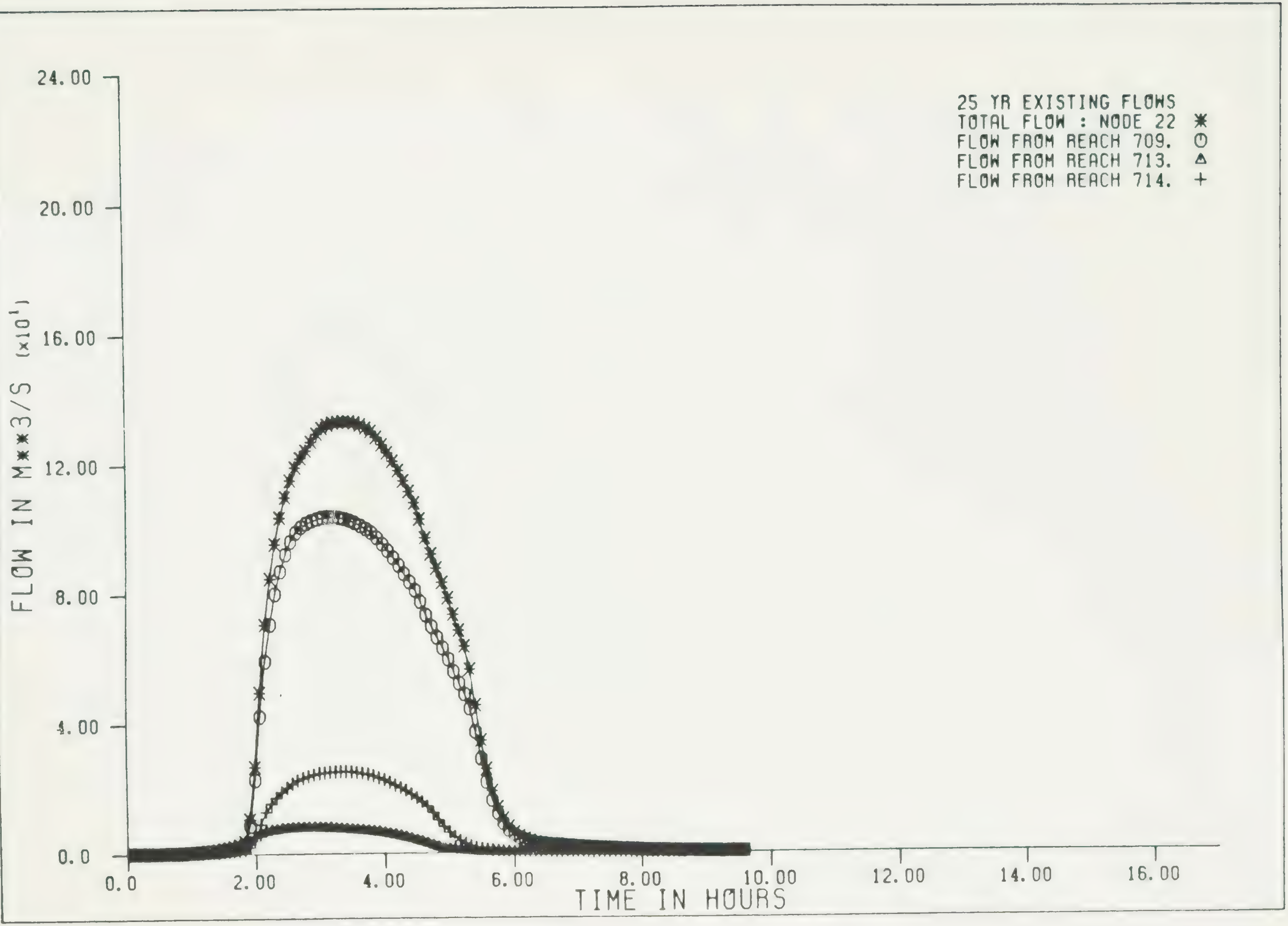
5 YR EXISTING FLOWS
TOTAL FLOW : NODE 22
FLOW FROM REACH 709.
FLOW FROM REACH 713.
FLOW FROM REACH 714.
12.00
10.00
8.00
6.00
4.00
2.00
0.0
FLOW IN M**3/S (x10¹)
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

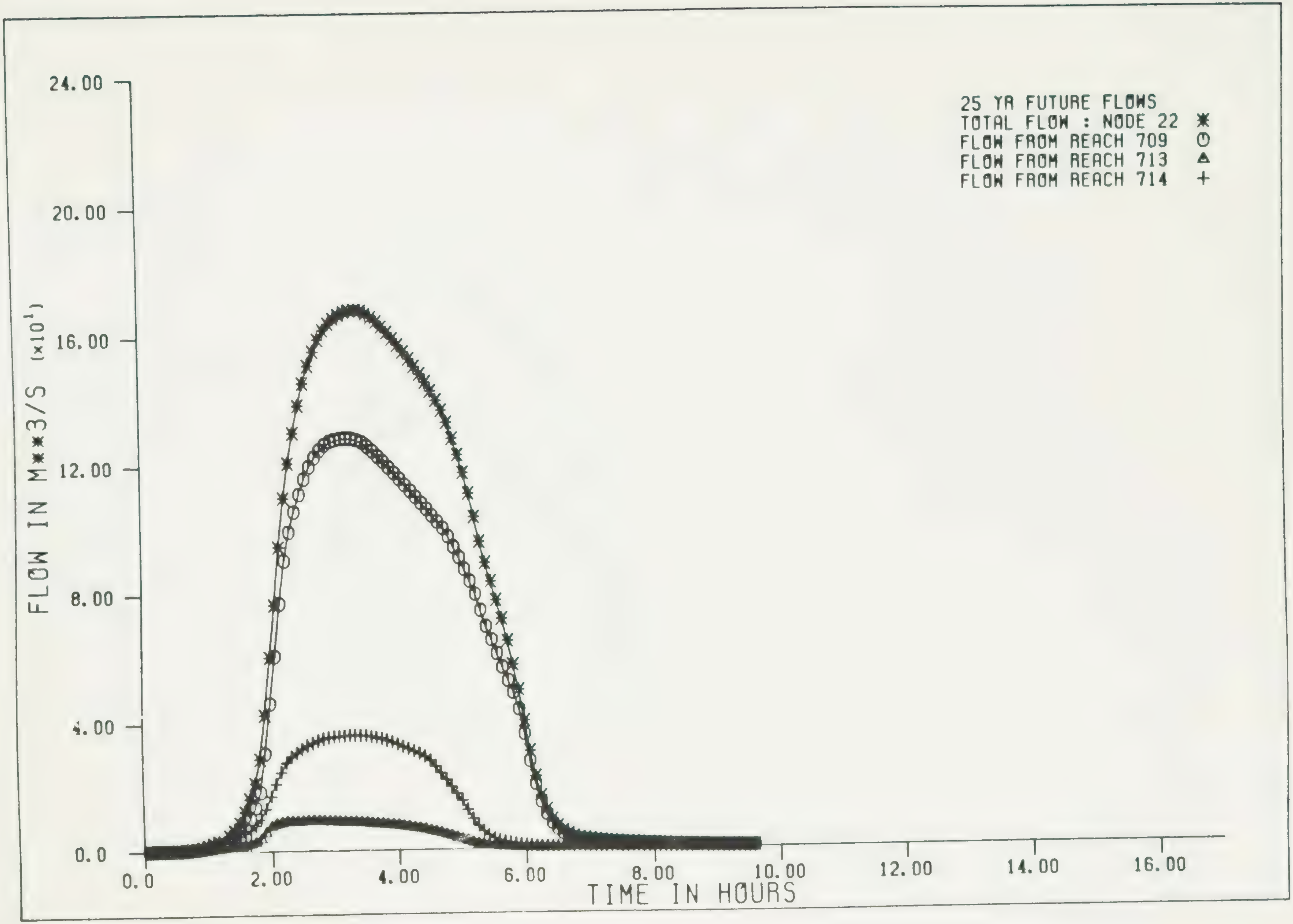

5 YEAR FUTURE FLOWS
TOTAL FLOW : NODE 22
FLOW FROM REACH 709
FLOW FROM REACH 713.
FLOW FROM REACH 714.
FLOW IN M**3/S (x10^1)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

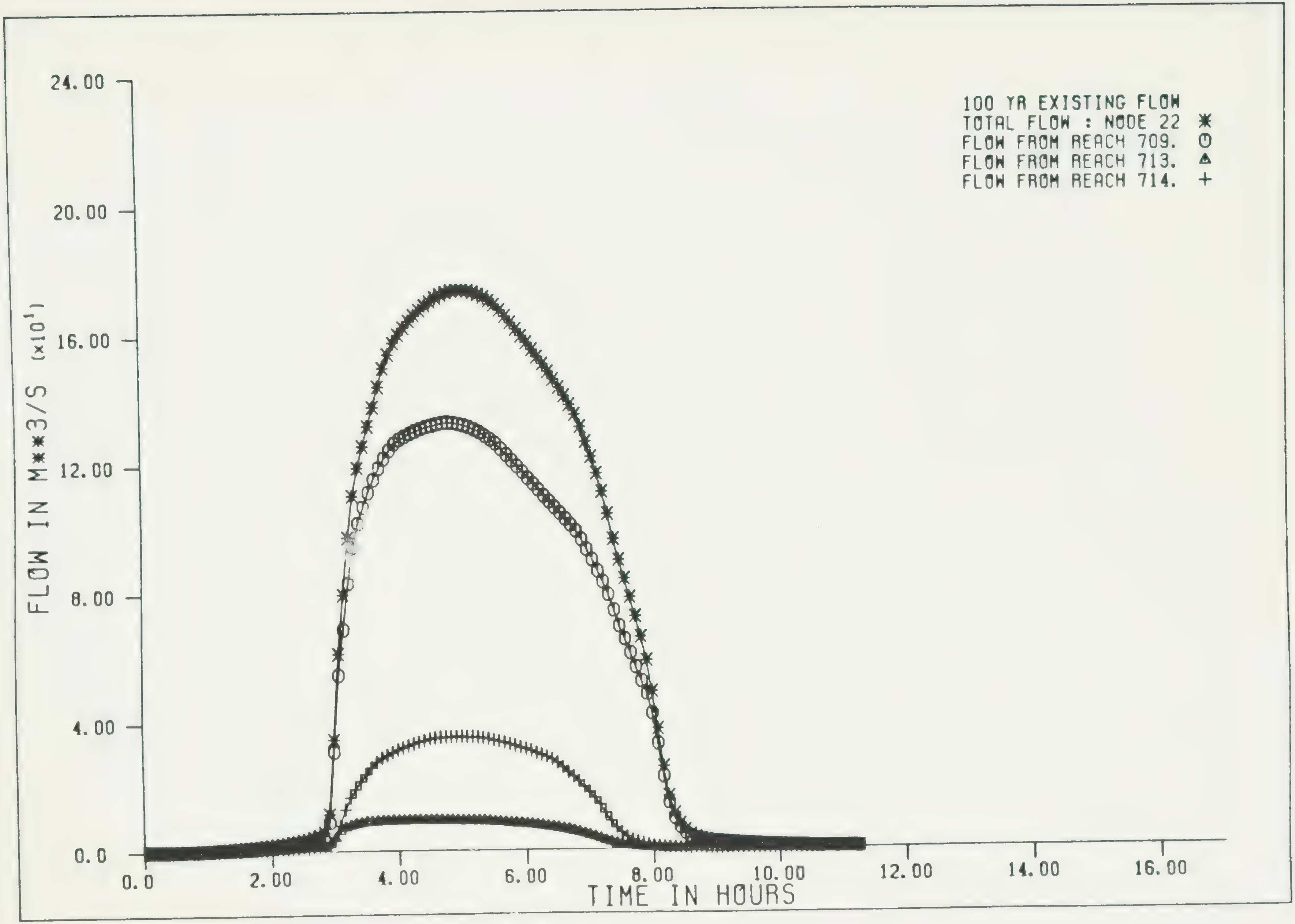


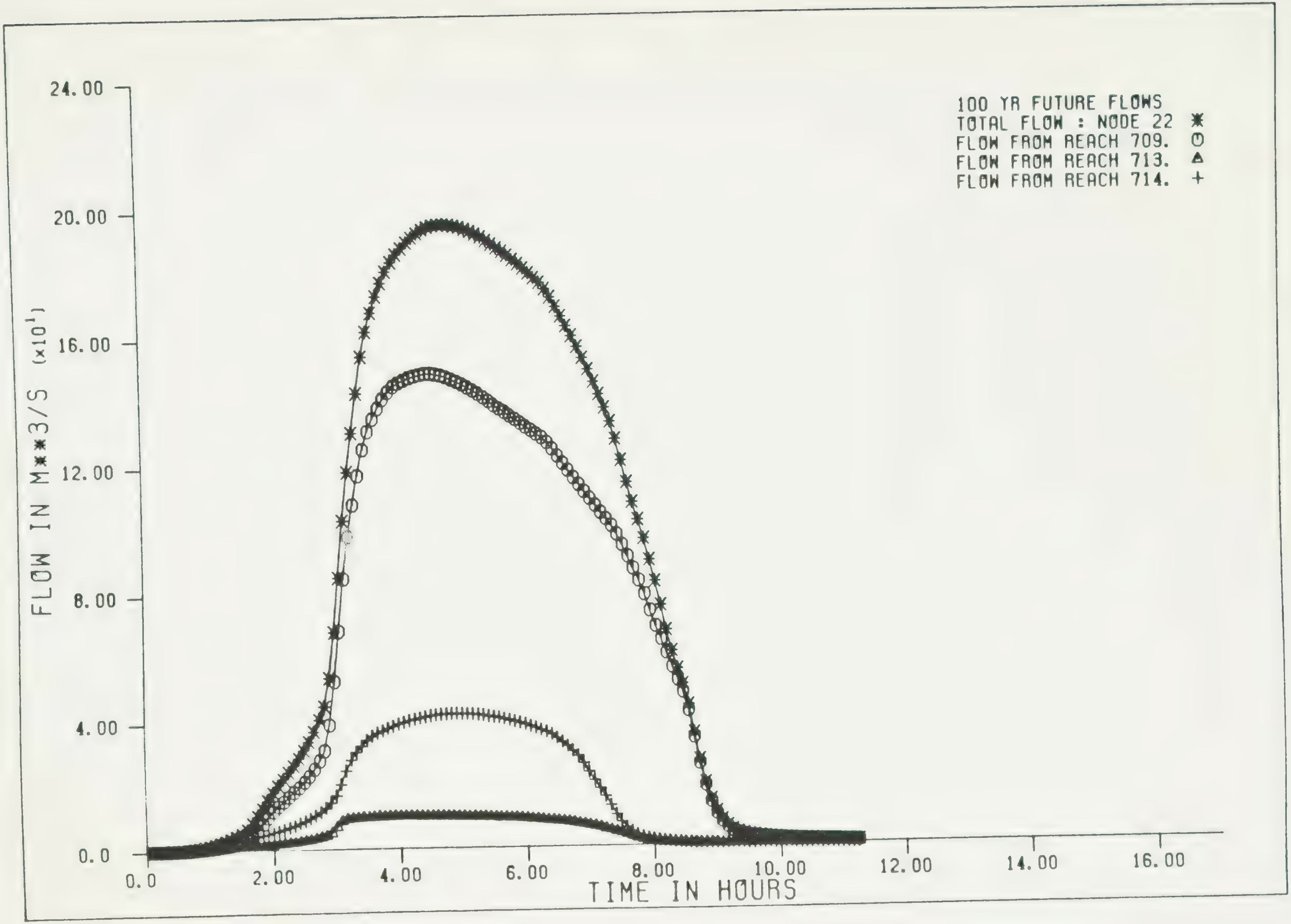
10 YR EXISTING FLOWS
TOTAL FLOW : NODE 22 ✱
FLOW FROM REACH 709. ⊙
FLOW FROM REACH 713. △
FLOW FROM REACH 714. +
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


10 YR FUTURE FLOWS.
TOTAL FLOW : NODE 22 ✱
FLOW FROM REACH 709. ⊖
FLOW FROM REACH 713. △
FLOW FROM REACH 714. +
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

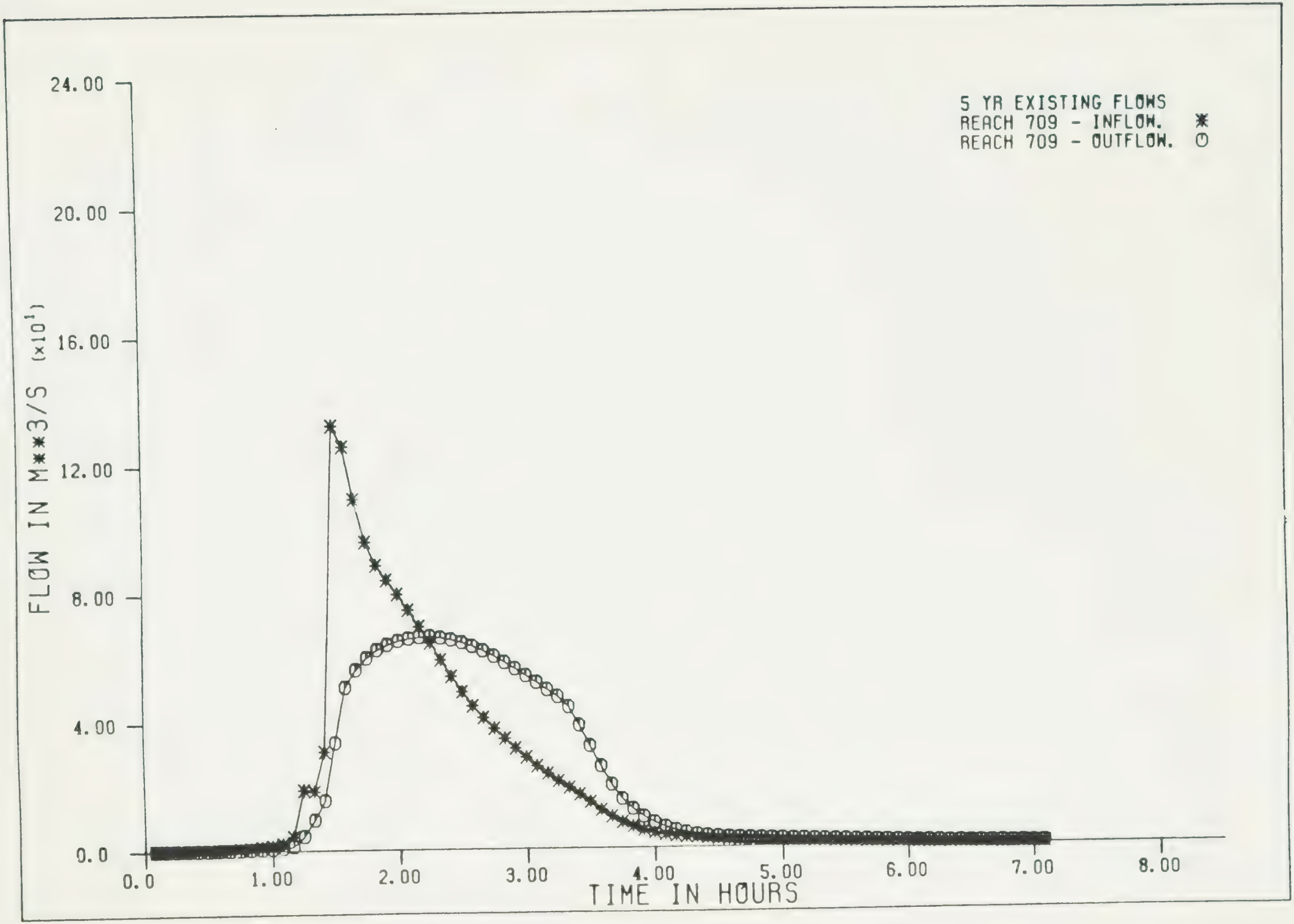

25 YR EXISTING FLOWS
TOTAL FLOW : NODE 22 ✱
FLOW FROM REACH 709. ○
FLOW FROM REACH 713. △
FLOW FROM REACH 714. +
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

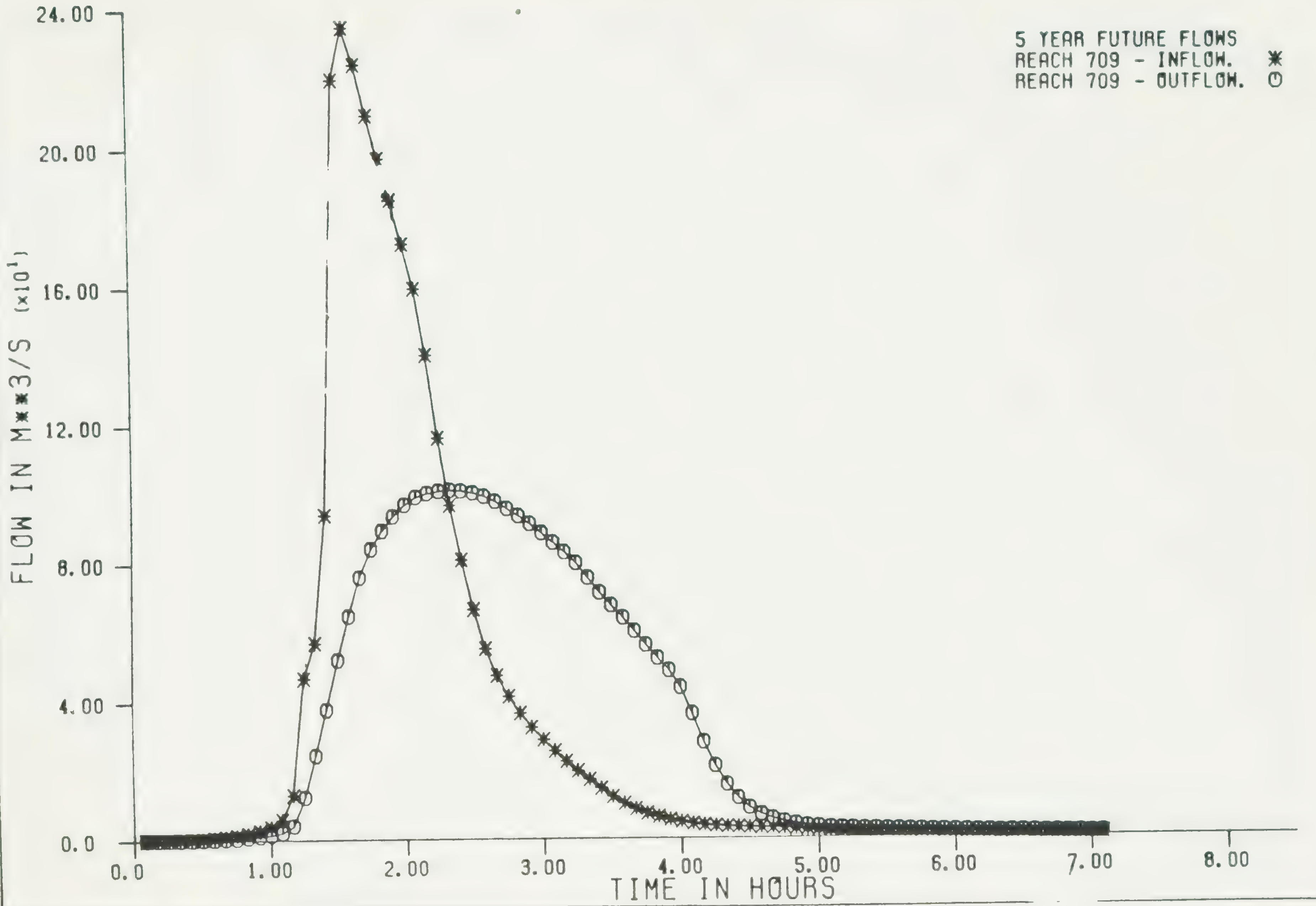

25 YR FUTURE FLOWS
TOTAL FLOW : NODE 22
FLOW FROM REACH 709
FLOW FROM REACH 713
FLOW FROM REACH 714
FLOW IN M**3/S (x10¹)
TIME IN HOURS
24.00
20.00
16.00
12.00
8.00
4.00
0.0
2.00
6.00
10.00
12.00
14.00
16.00

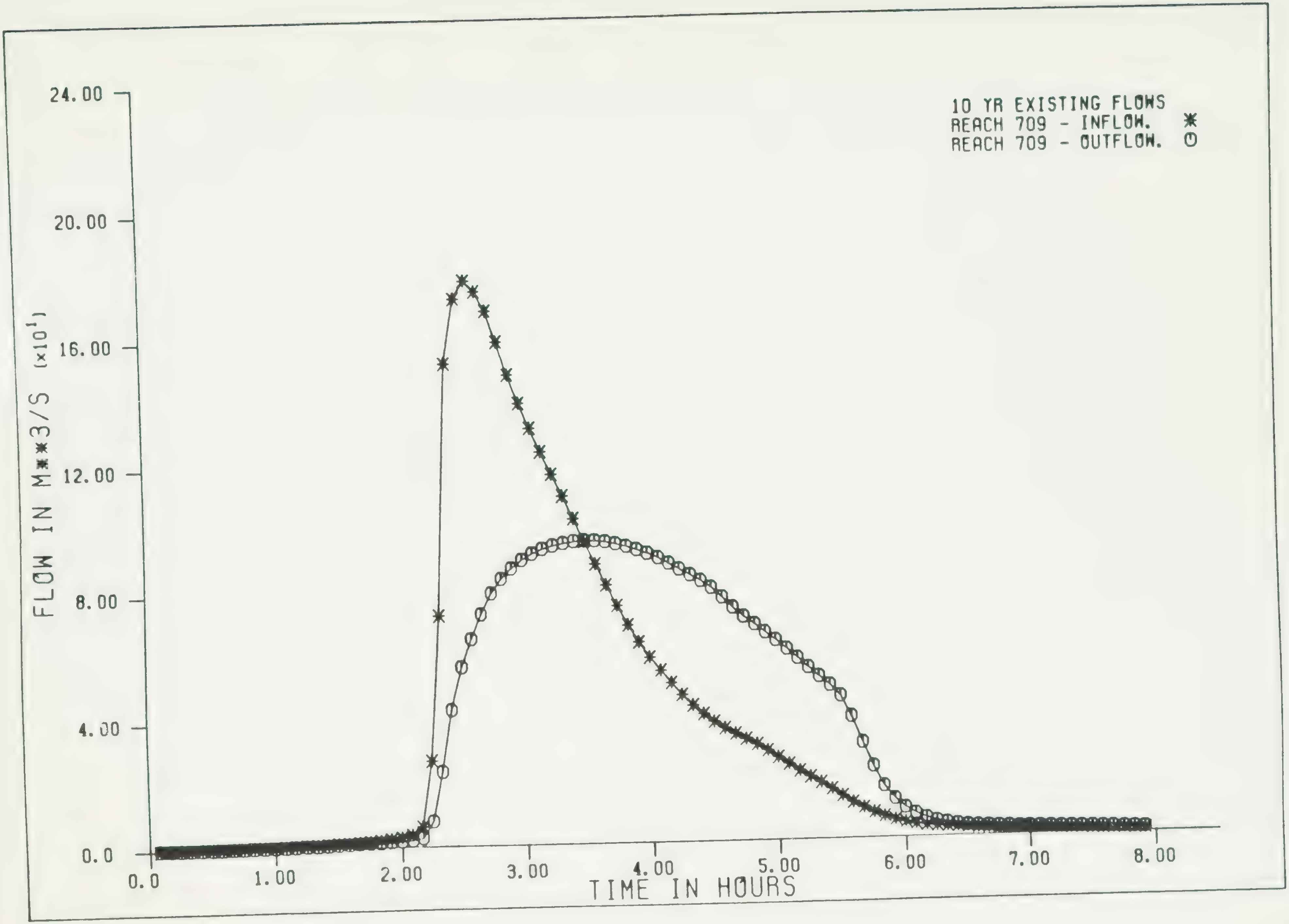

100 YR EXISTING FLOW
TOTAL FLOW : NODE 22
FLOW FROM REACH 709.
FLOW FROM REACH 713.
FLOW FROM REACH 714.
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

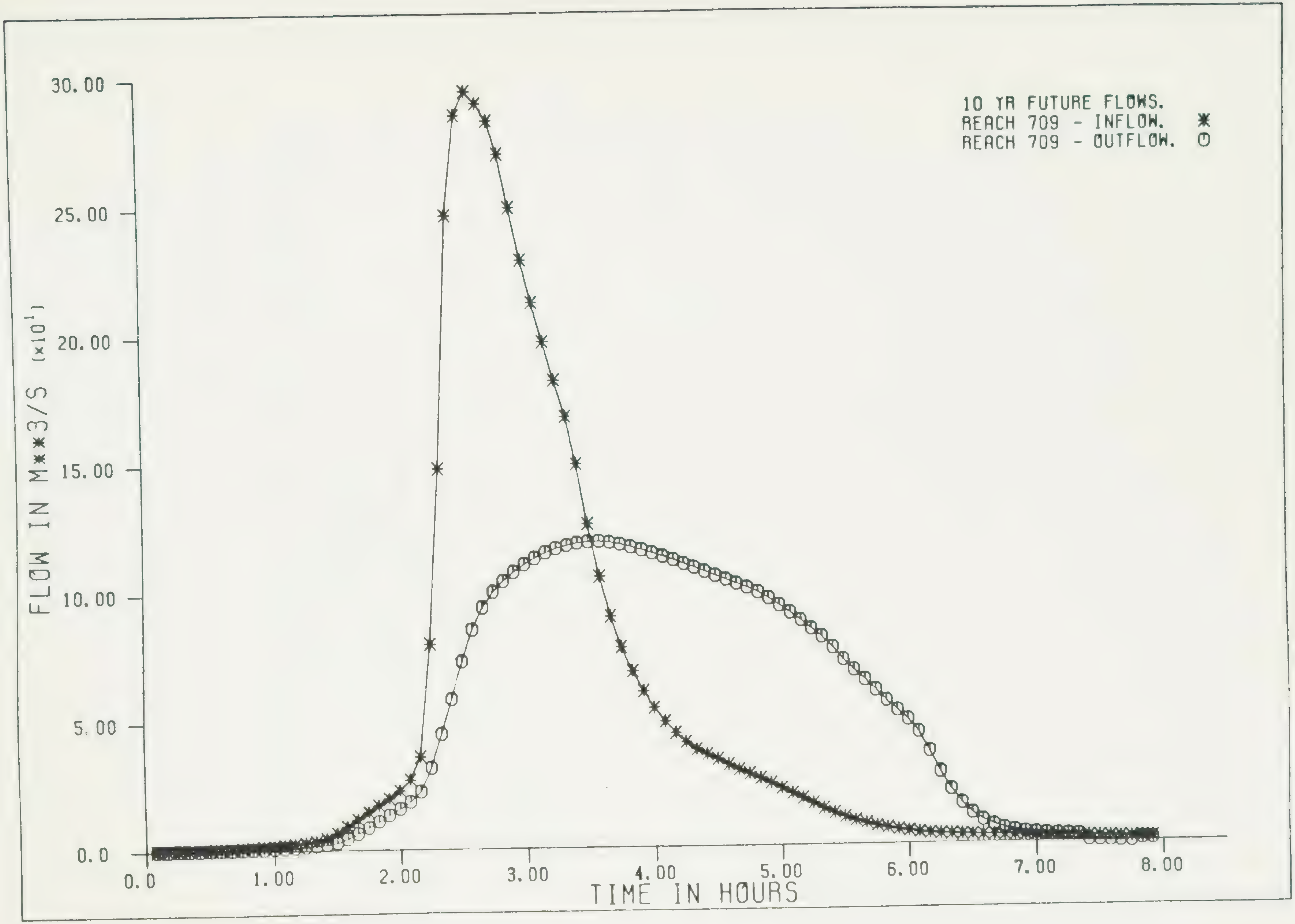

100 YR FUTURE FLOWS
TOTAL FLOW : NODE 22 ✱
FLOW FROM REACH 709. ⊖
FLOW FROM REACH 713. △
FLOW FROM REACH 714. +
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

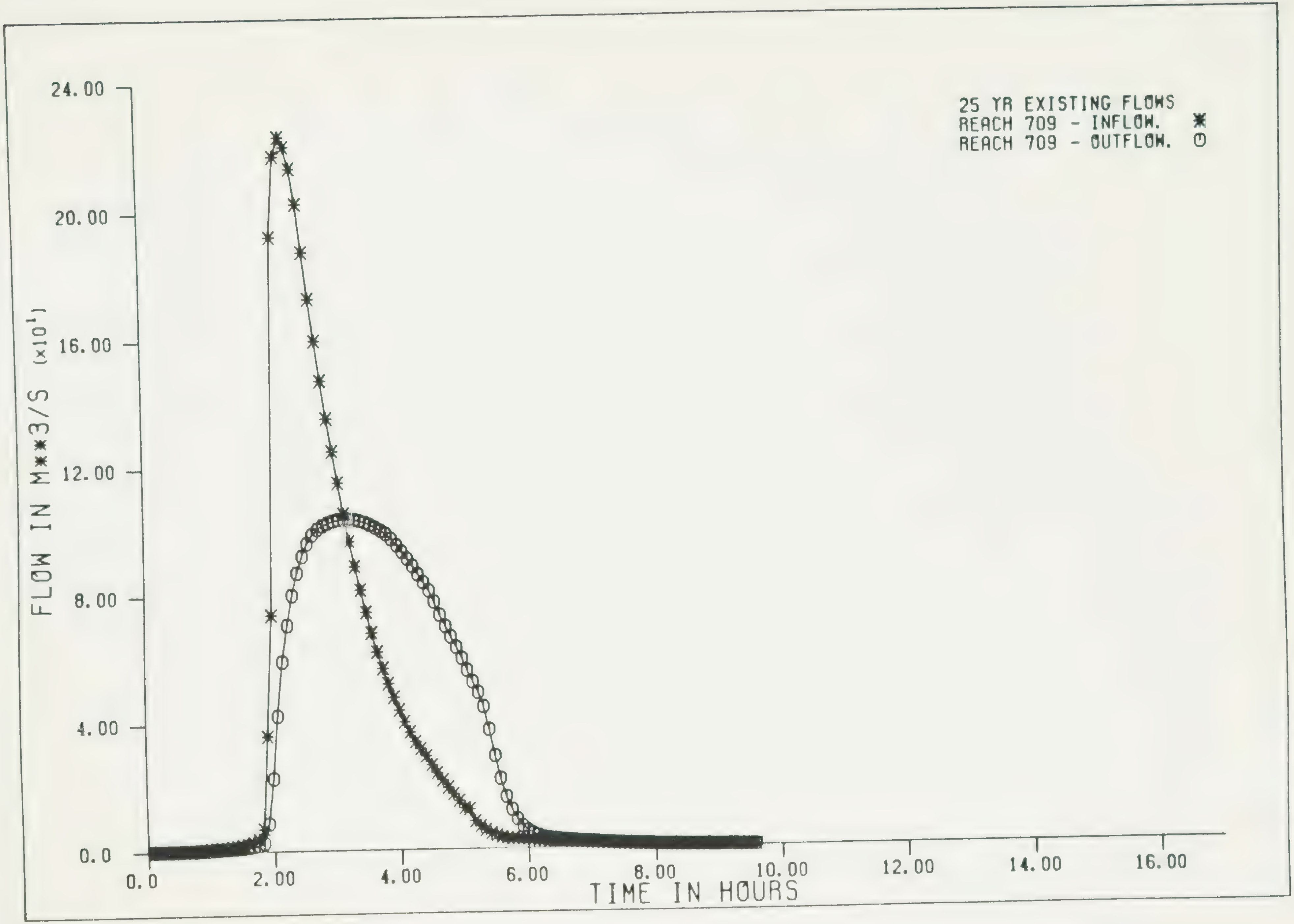
Hydrograph Set No. 3:
Inflow and Outflow Hydrographs for
Stream Reaches with Significant Storage

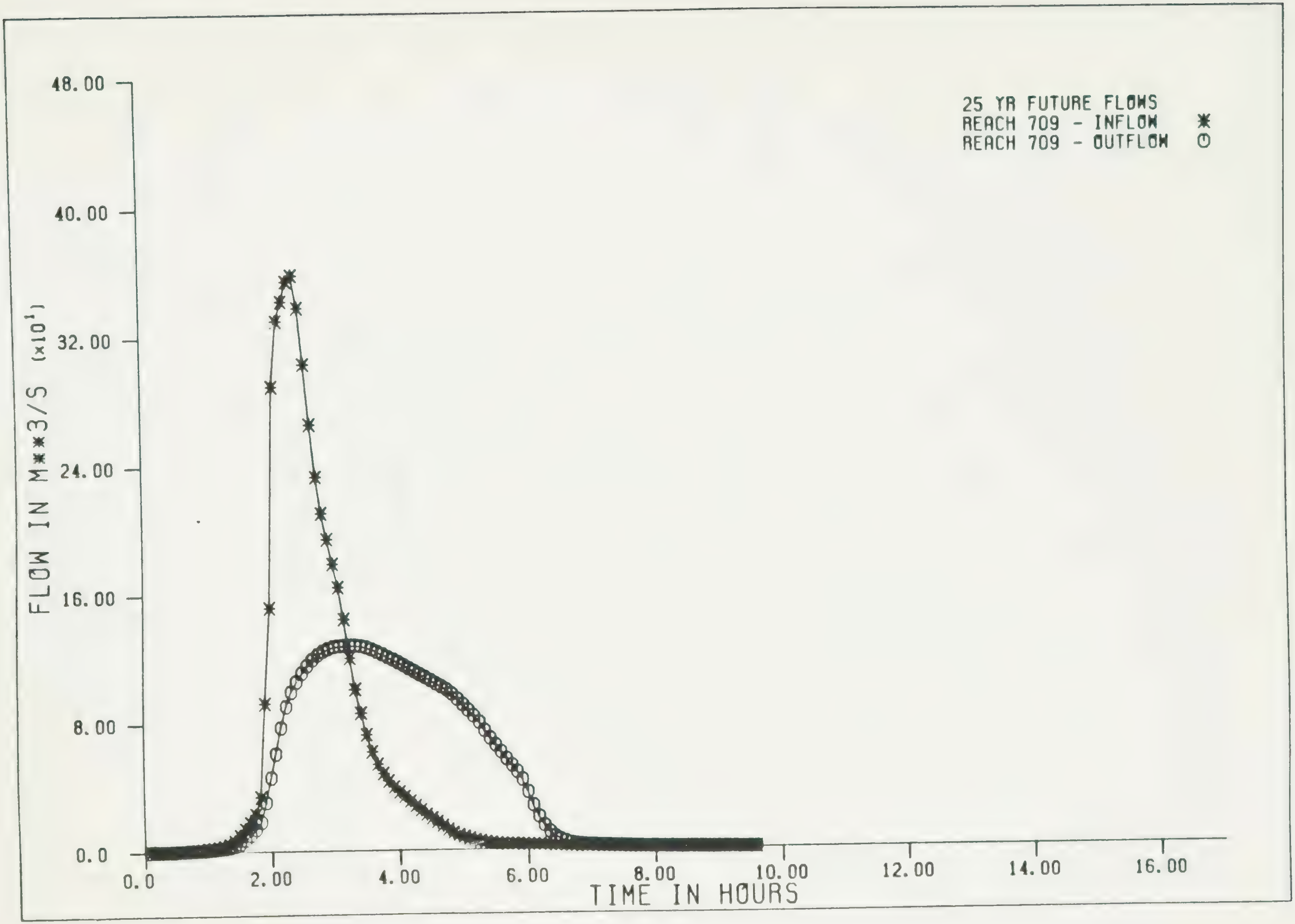

5 YR EXISTING FLOWS
REACH 709 - INFLOW. ✱
REACH 709 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

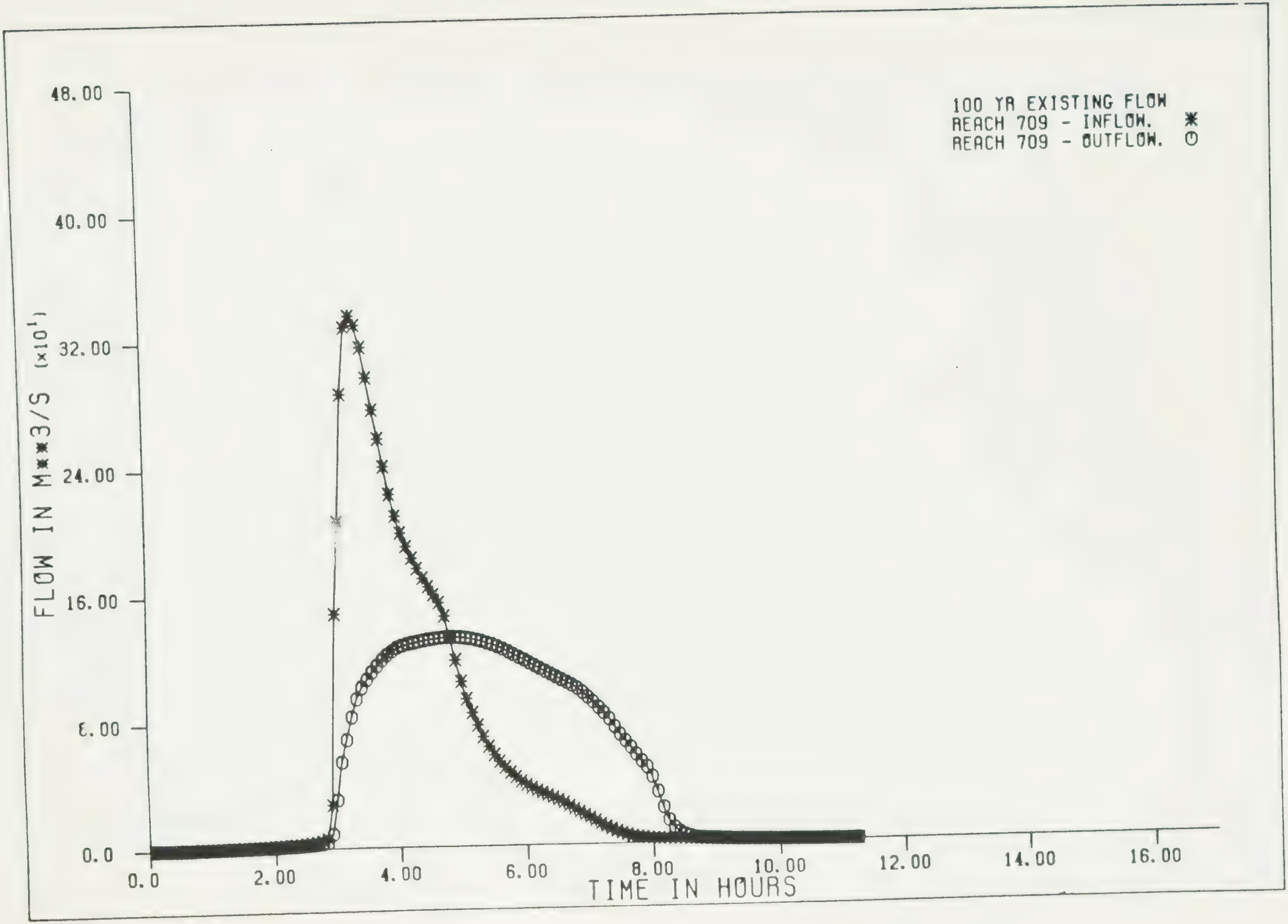

5 YEAR FUTURE FLOWS
REACH 709 - INFLOW. *
REACH 709 - OUTFLOW. O
FLOW IN M**3/S (x10^1)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


10 YR EXISTING FLOWS
REACH 709 - INFLOW. *
REACH 709 - OUTFLOW. O
FLOW IN M**3/S (x10^1)
TIME IN HOURS
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

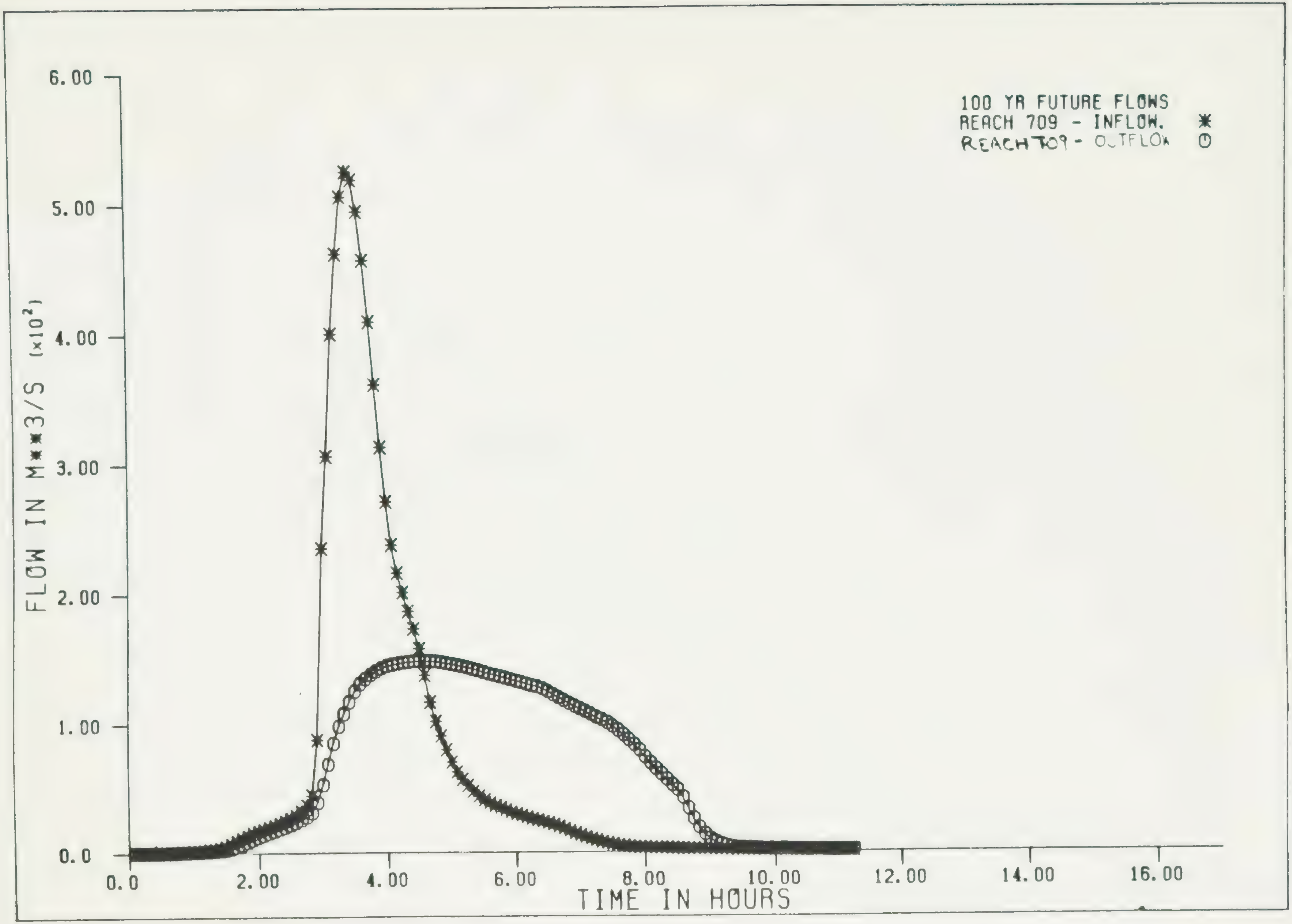

10 YR FUTURE FLOWS.
REACH 709 - INFLOW. *
REACH 709 - OUTFLOW. O
30.00
25.00
20.00
15.00
10.00
5.00
0.0
FLOW IN M**3/S (x10¹)
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

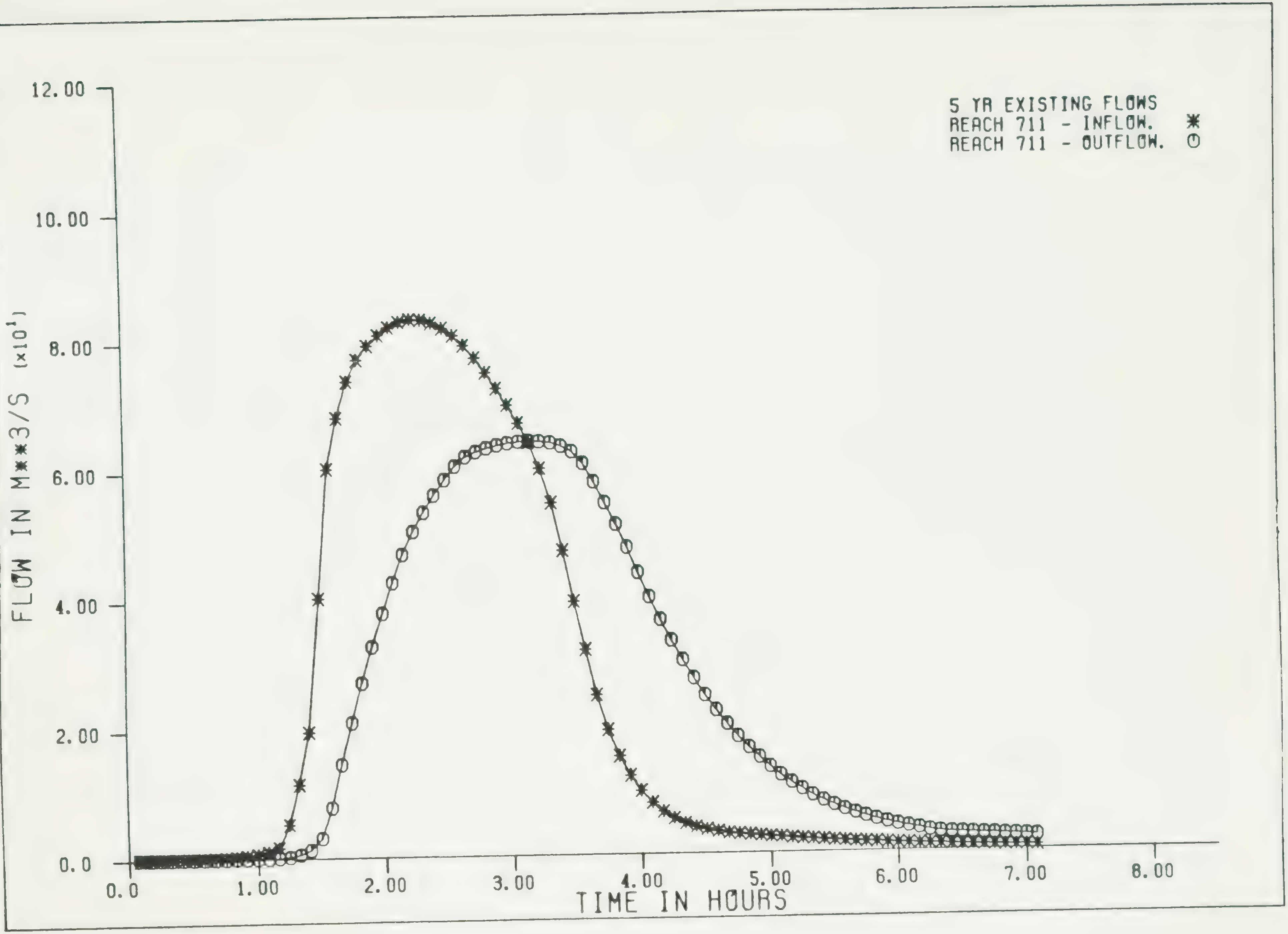

25 YR EXISTING FLOWS
REACH 709 - INFLOW. *
REACH 709 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

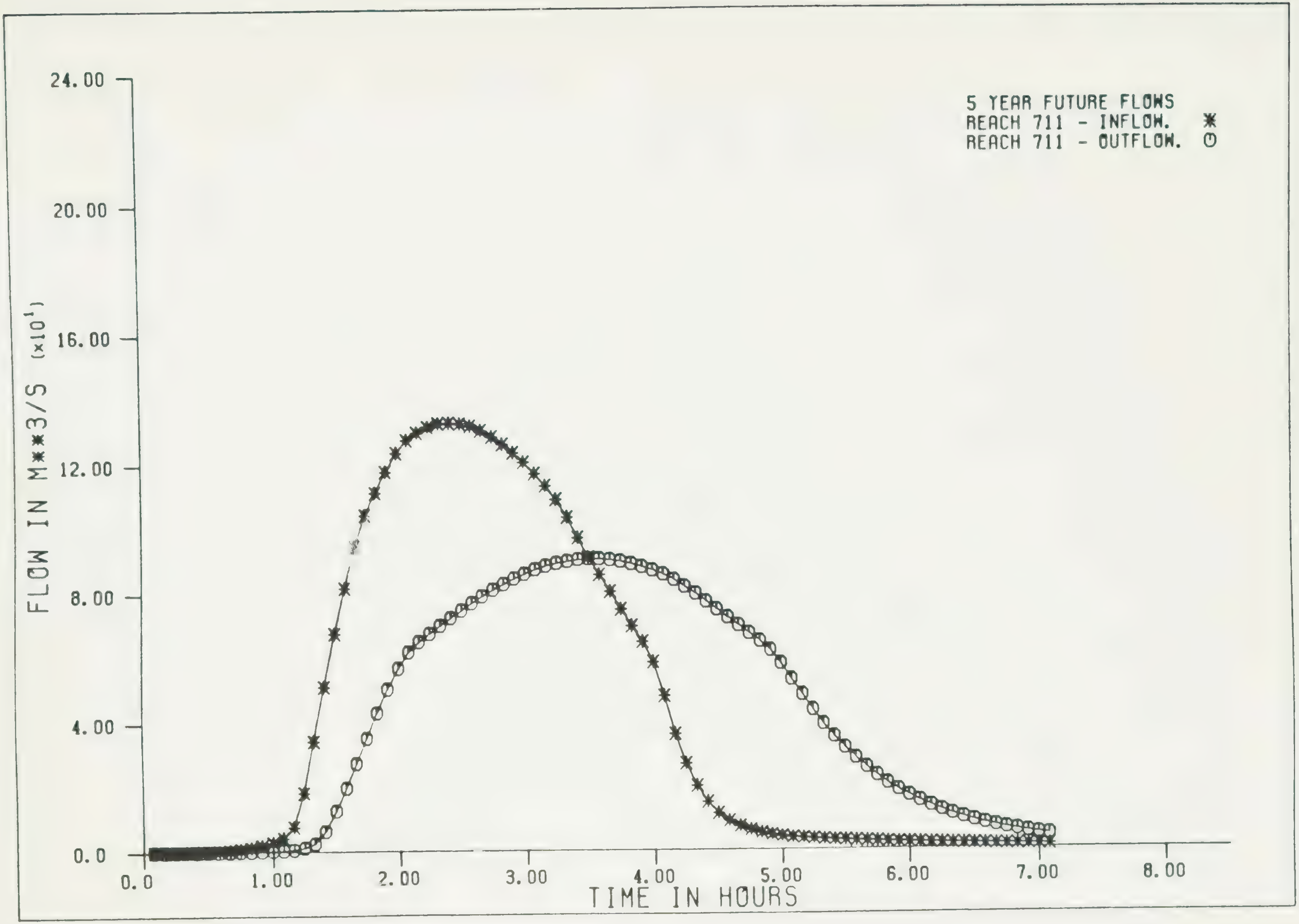

25 YR FUTURE FLOWS
REACH 709 - INFLOW *
REACH 709 - OUTFLOW O
FLOW IN M**3/S (x10¹)
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS



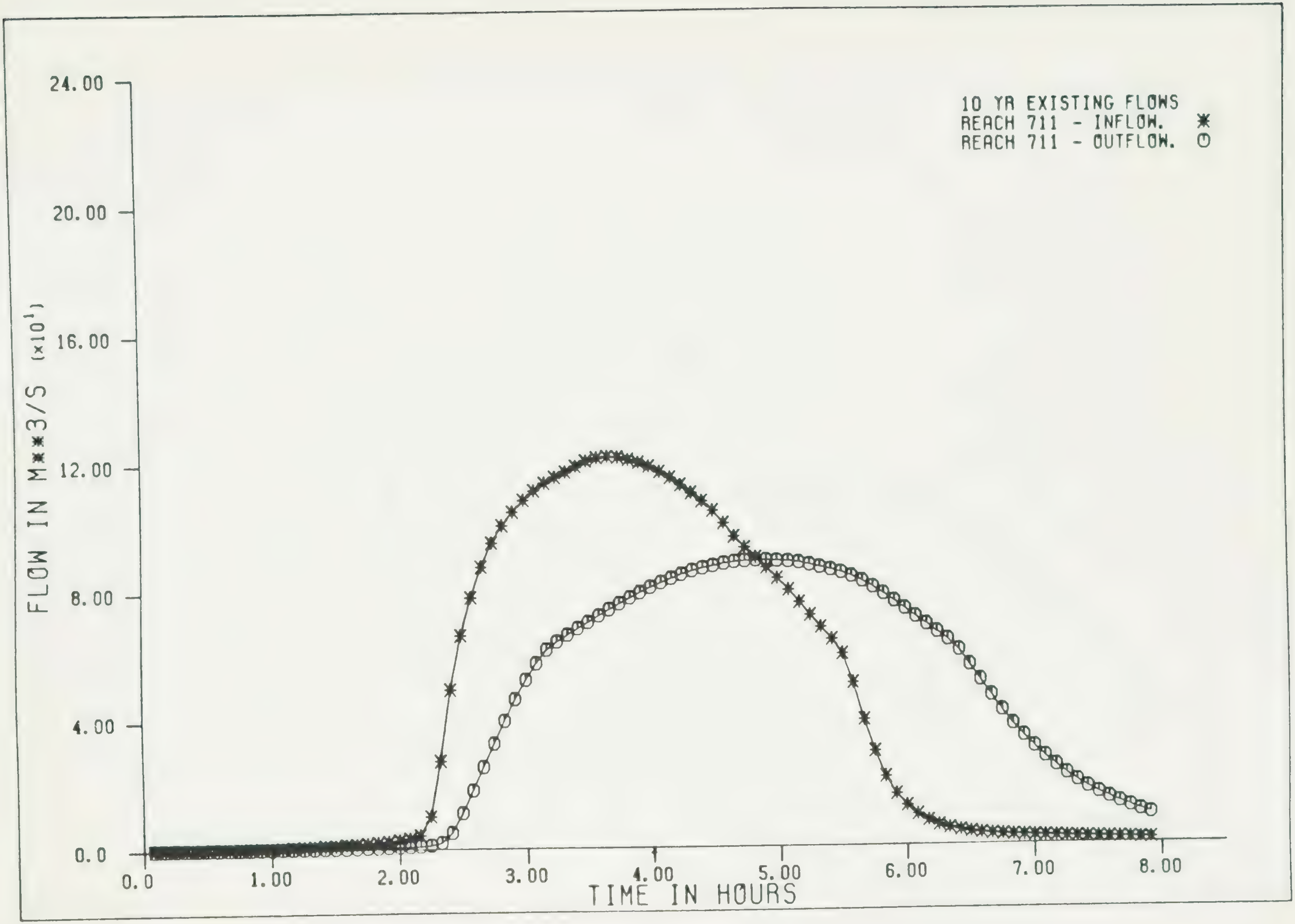
100 YR EXISTING FLOW
REACH 709 - INFLOW. ✱
REACH 709 - OUTFLOW. ⊙
48.00
40.00
32.00
24.00
16.00
8.00
0.0
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

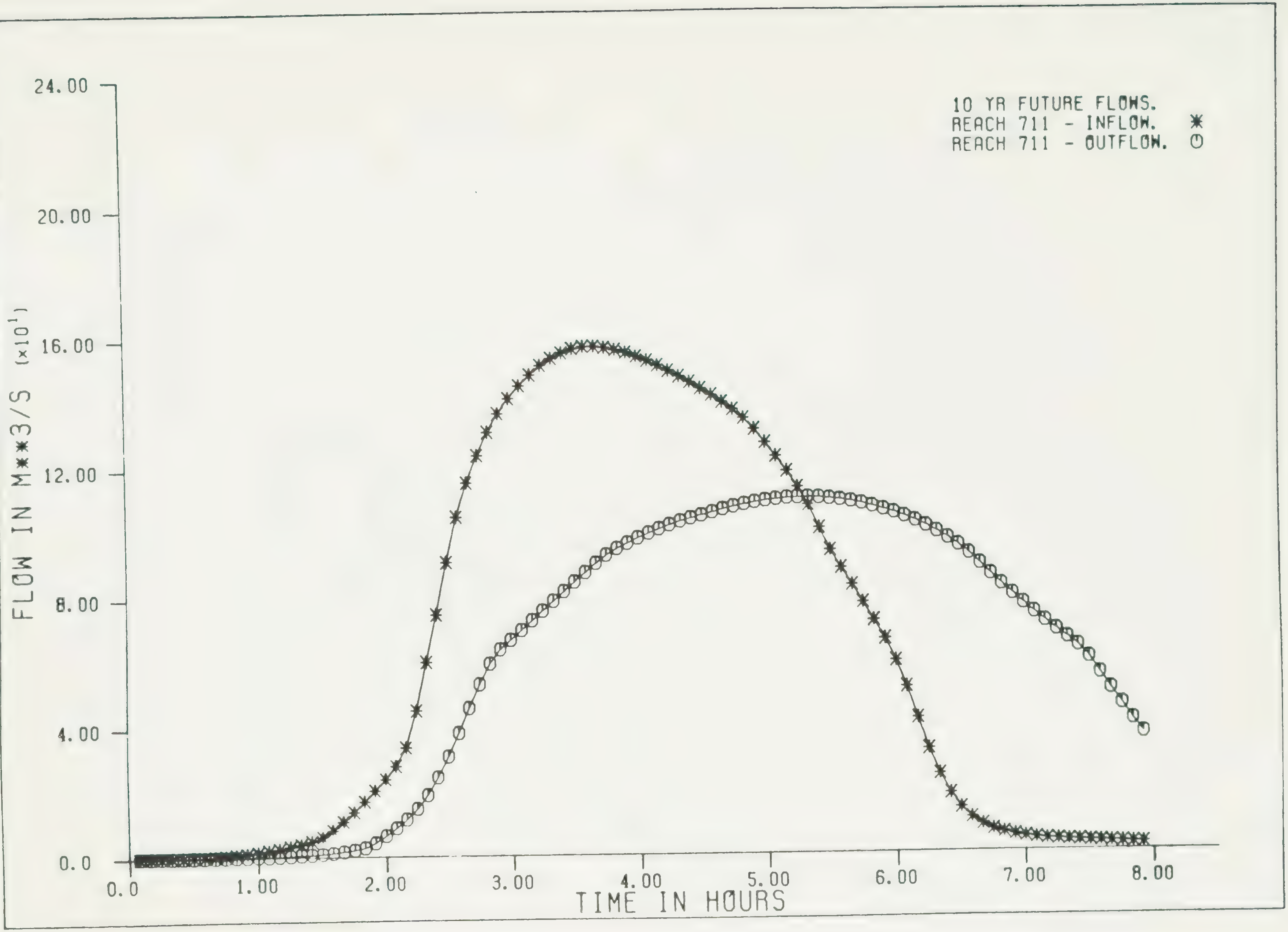

100 YR FUTURE FLOWS
REACH 709 - INFLOW. *
REACH 709 - OUTFLOW O
FLOW IN M**3/S (x10²)
6.00
5.00
4.00
3.00
2.00
1.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

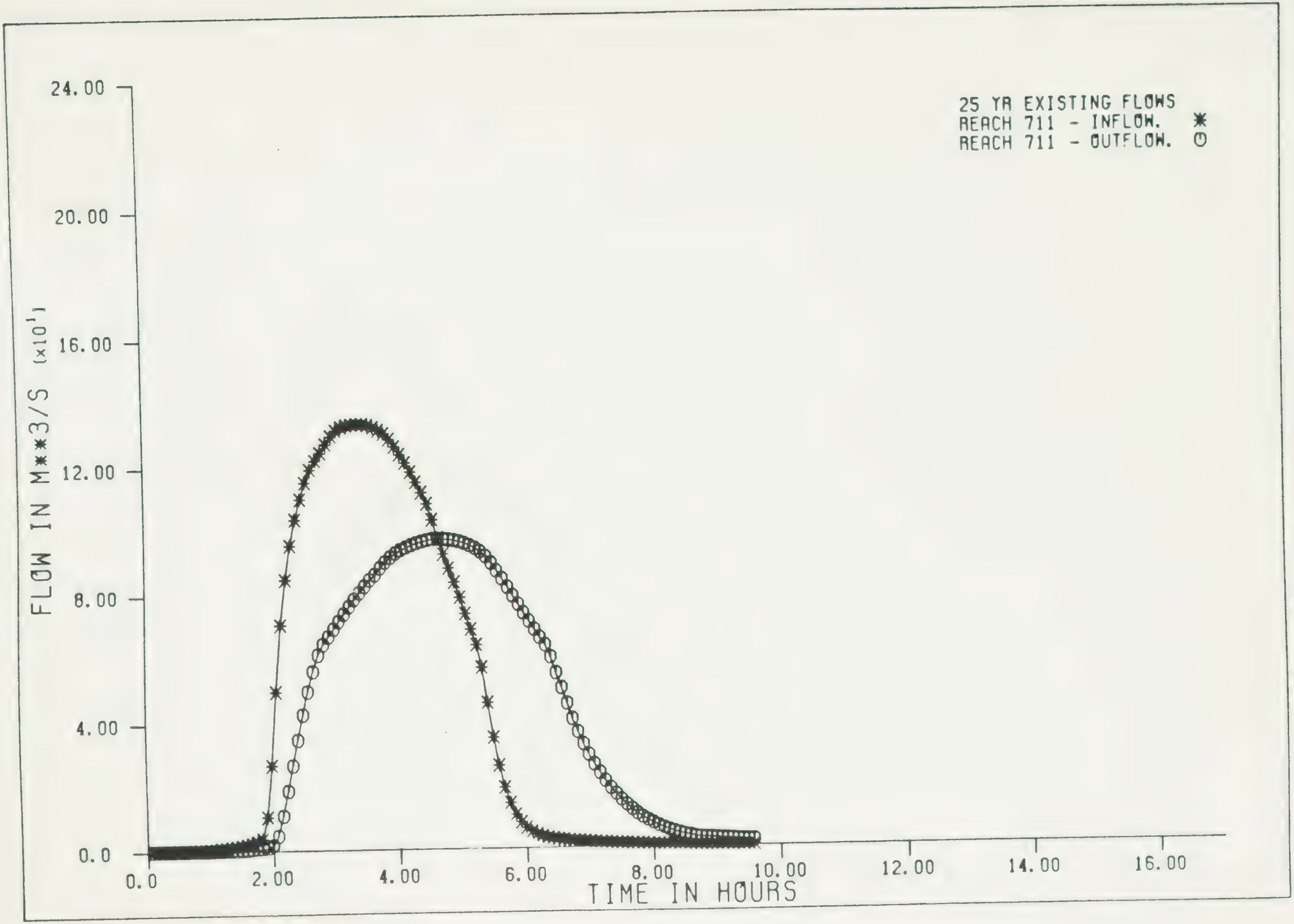

5 YR EXISTING FLOWS
REACH 711 - INFLOW. *
REACH 711 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

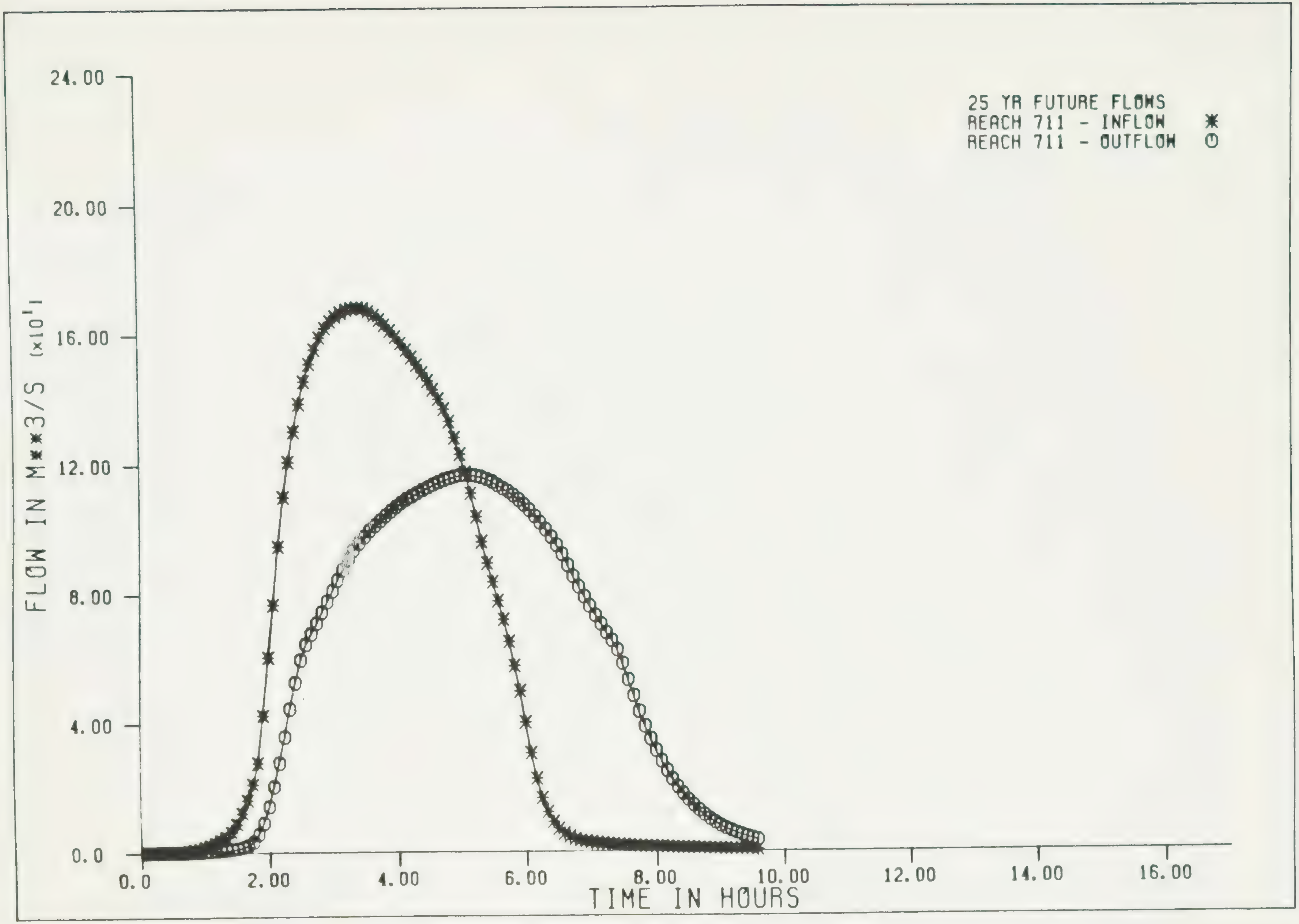


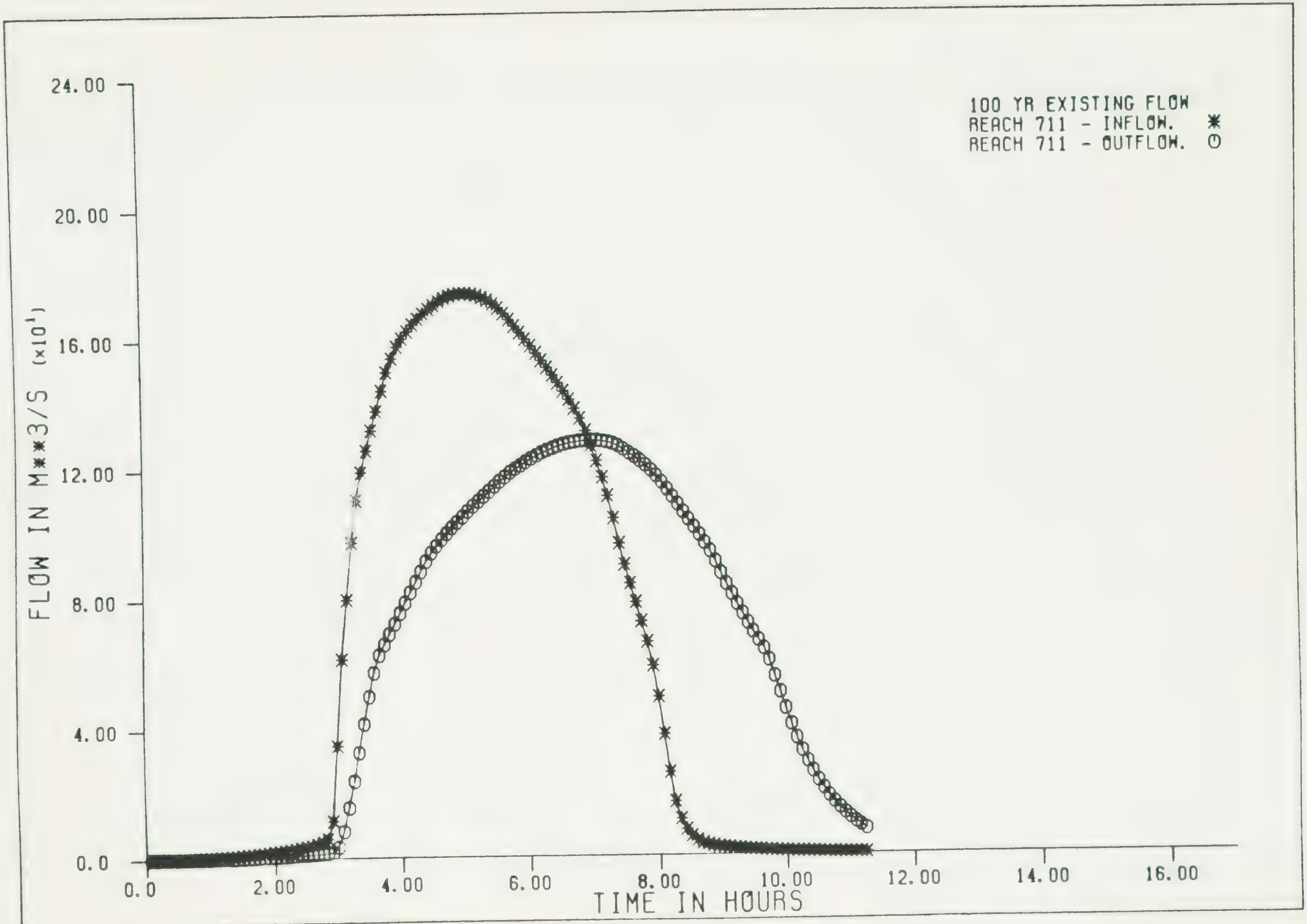
5 YEAR FUTURE FLOWS
REACH 711 - INFLOW. *
REACH 711 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


10 YR EXISTING FLOWS
REACH 711 - INFLOW. *
REACH 711 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

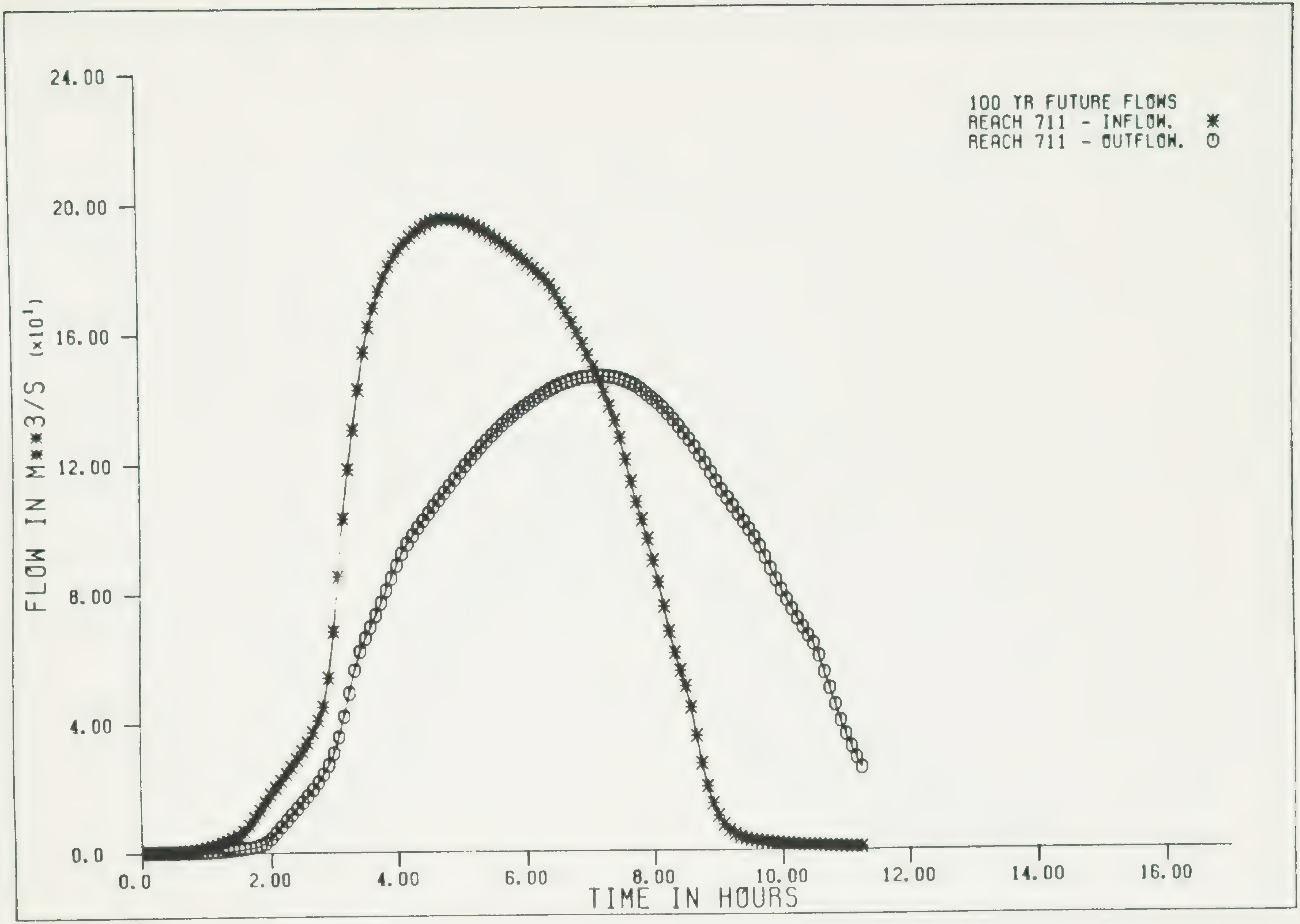

10 YR FUTURE FLOWS.
REACH 711 - INFLOW. *
REACH 711 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

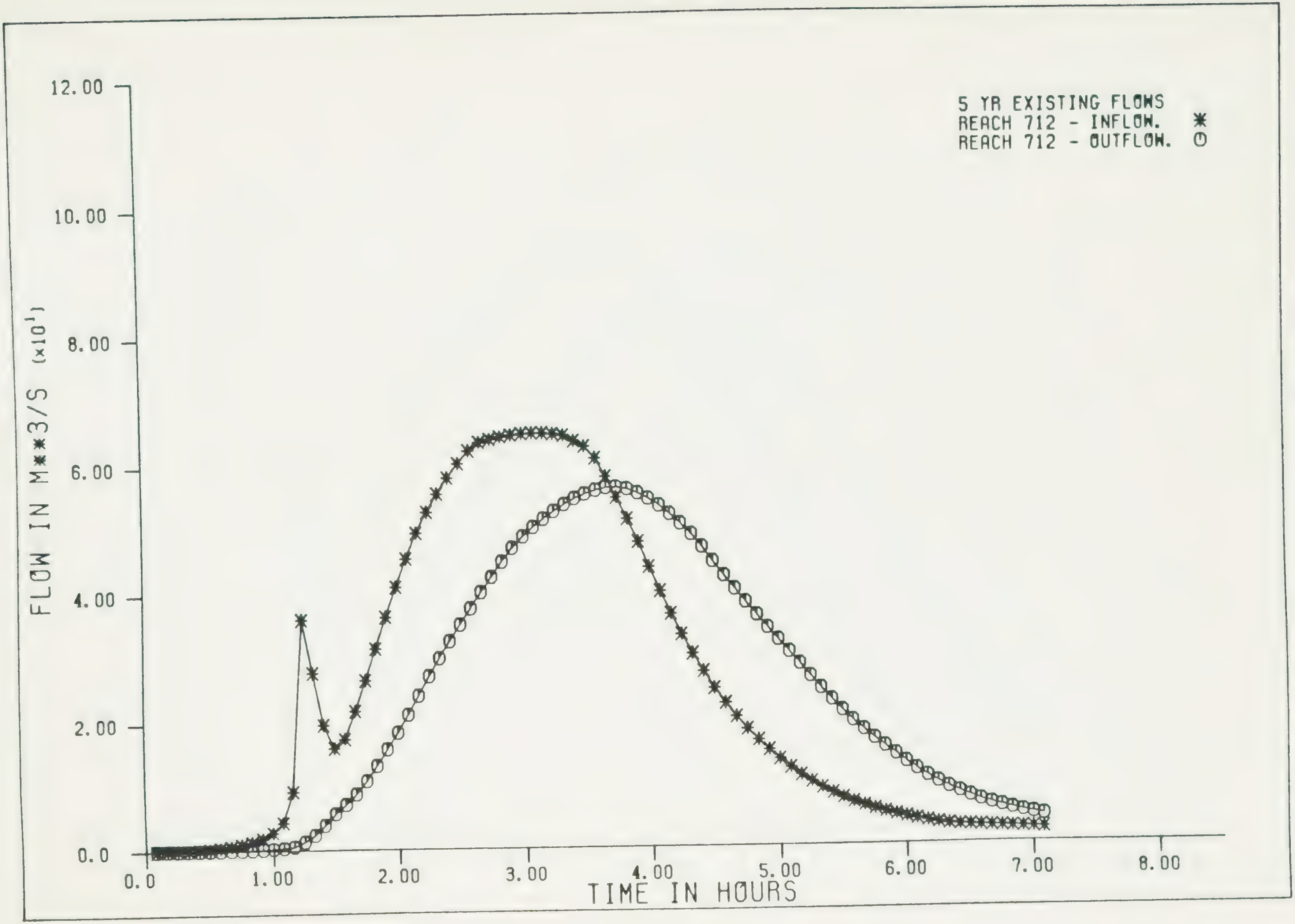

25 YR EXISTING FLOWS
REACH 711 - INFLOW. ✱
REACH 711 - OUTFLOW. ○
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS


25 YR FUTURE FLOWS
REACH 711 - INFLOW
REACH 711 - OUTFLOW
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

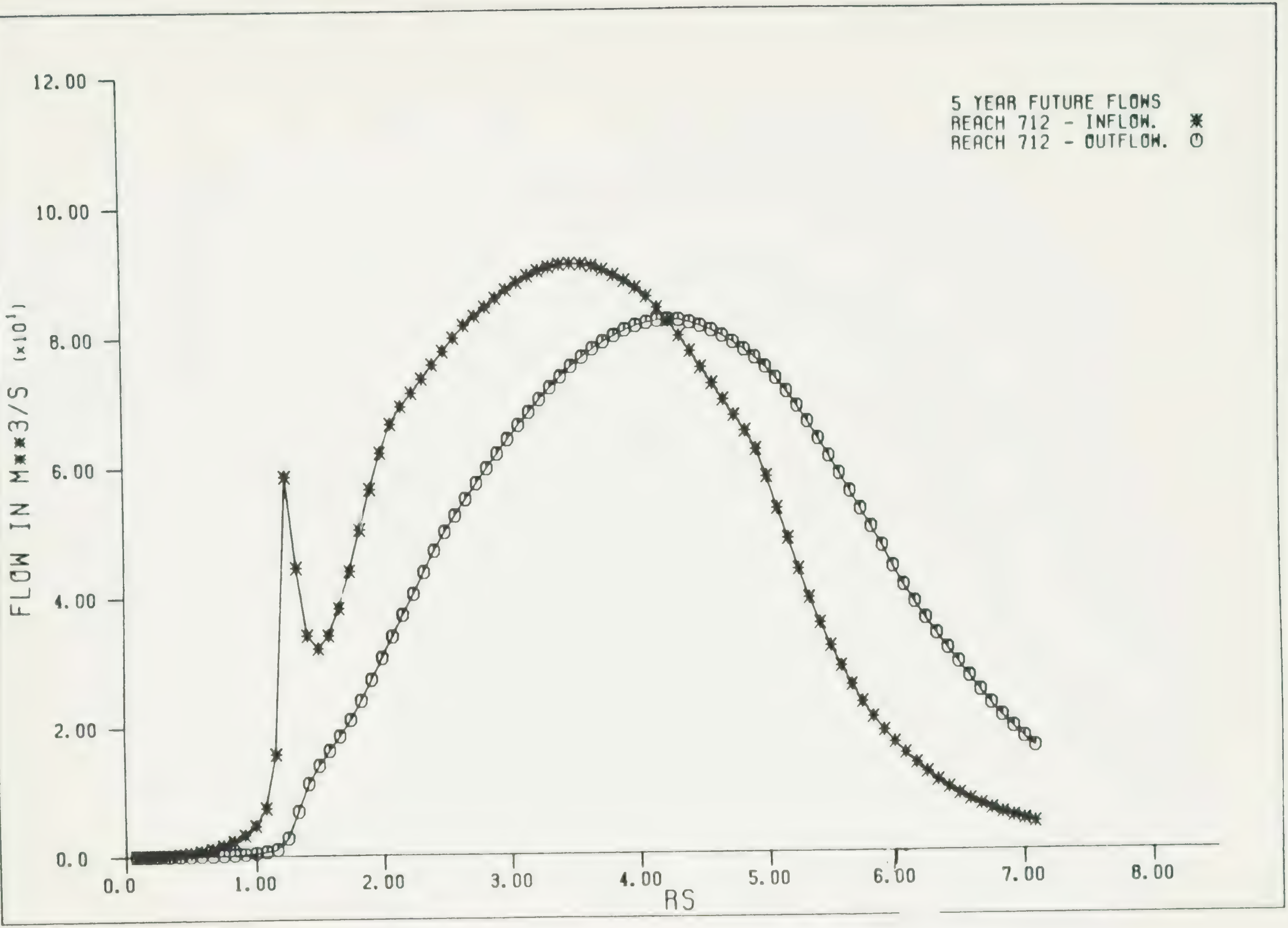


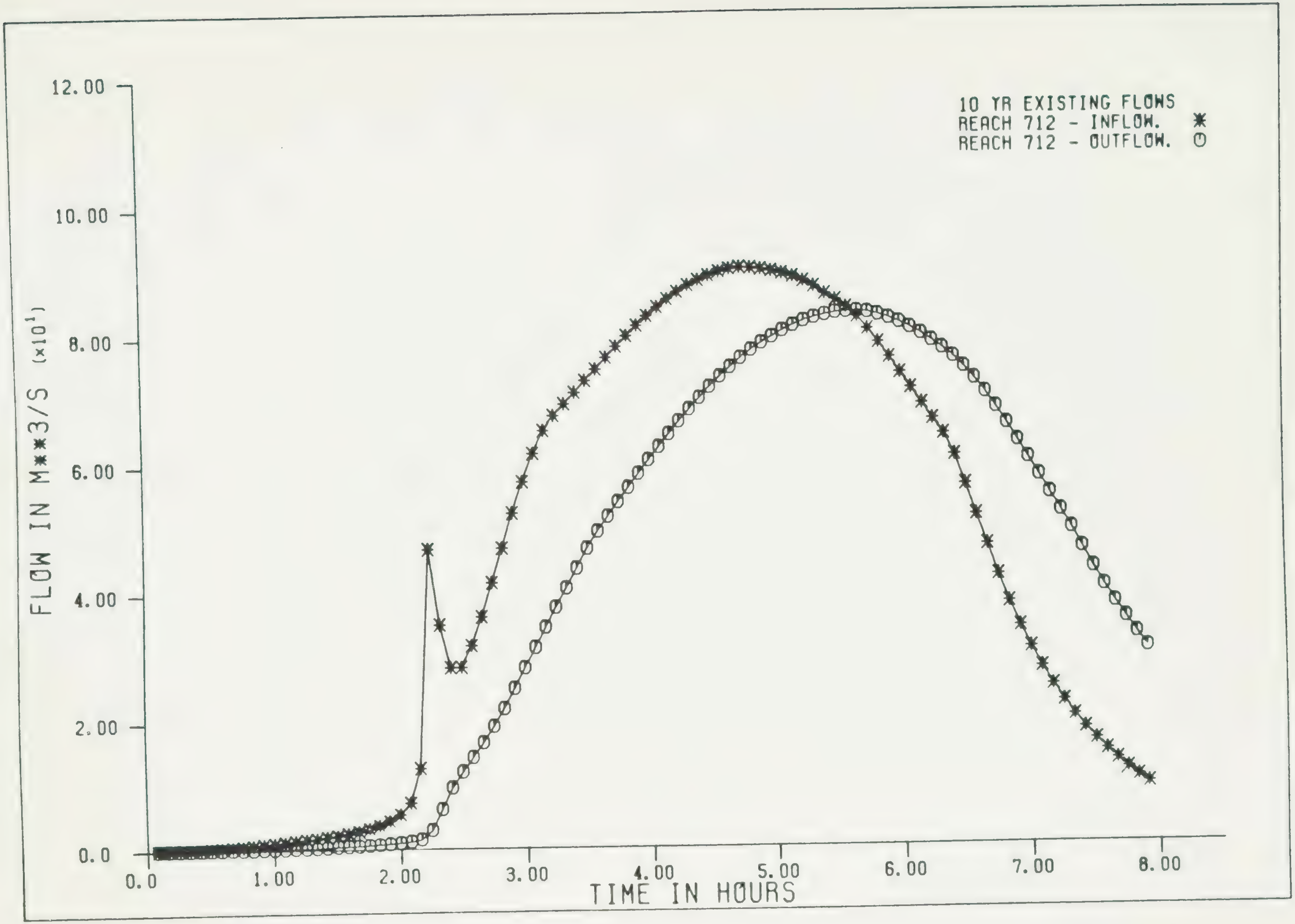
100 YR EXISTING FLOW
REACH 711 - INFLOW.
REACH 711 - OUTFLOW.
24.00
20.00
16.00
12.00
8.00
4.00
0.0
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

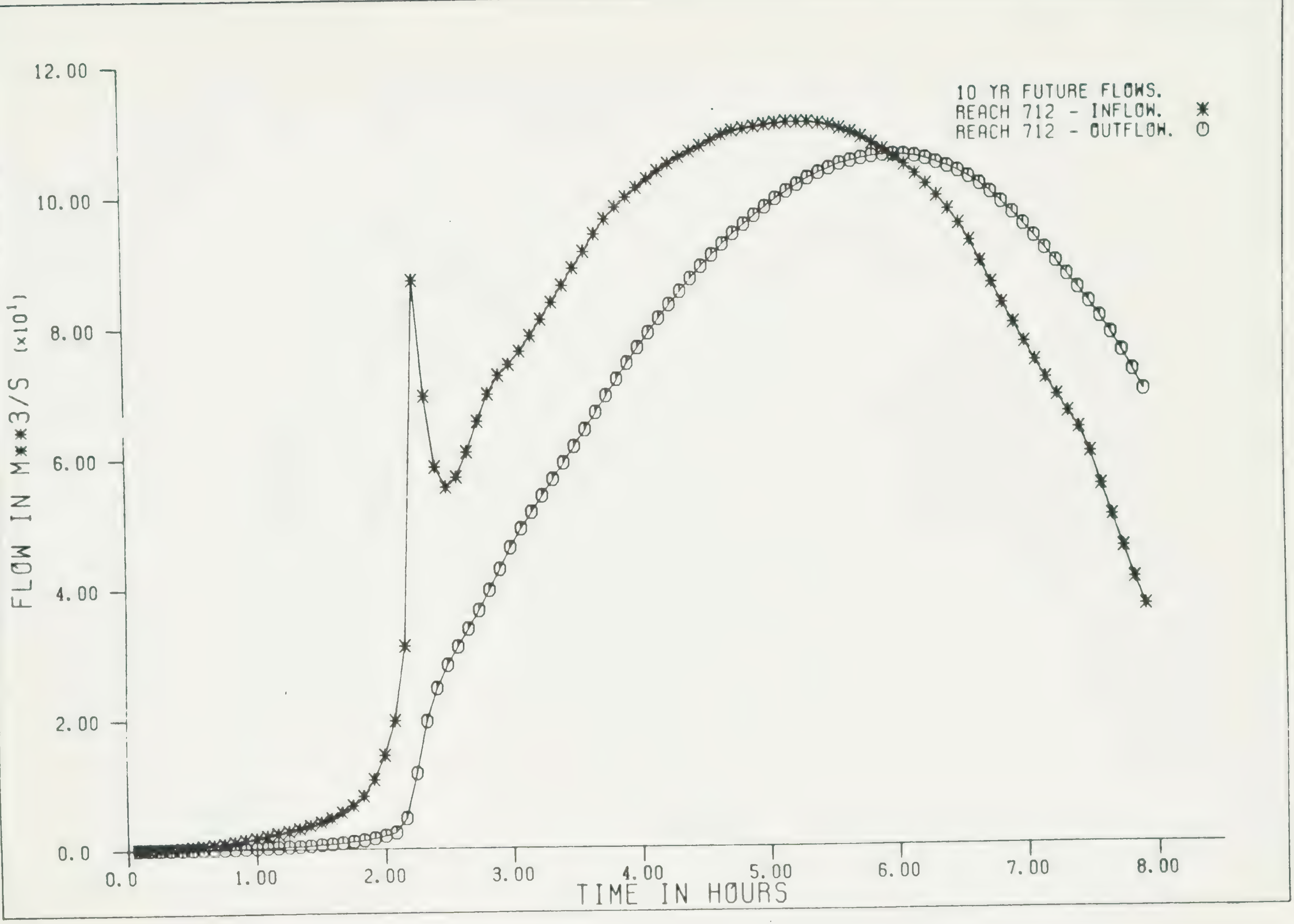

100 YR FUTURE FLOWS
REACH 711 - INFLOW. *
REACH 711 - OUTFLOW. O
FLOW IN M**3/S (x10[1])
TIME IN HOURS
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00

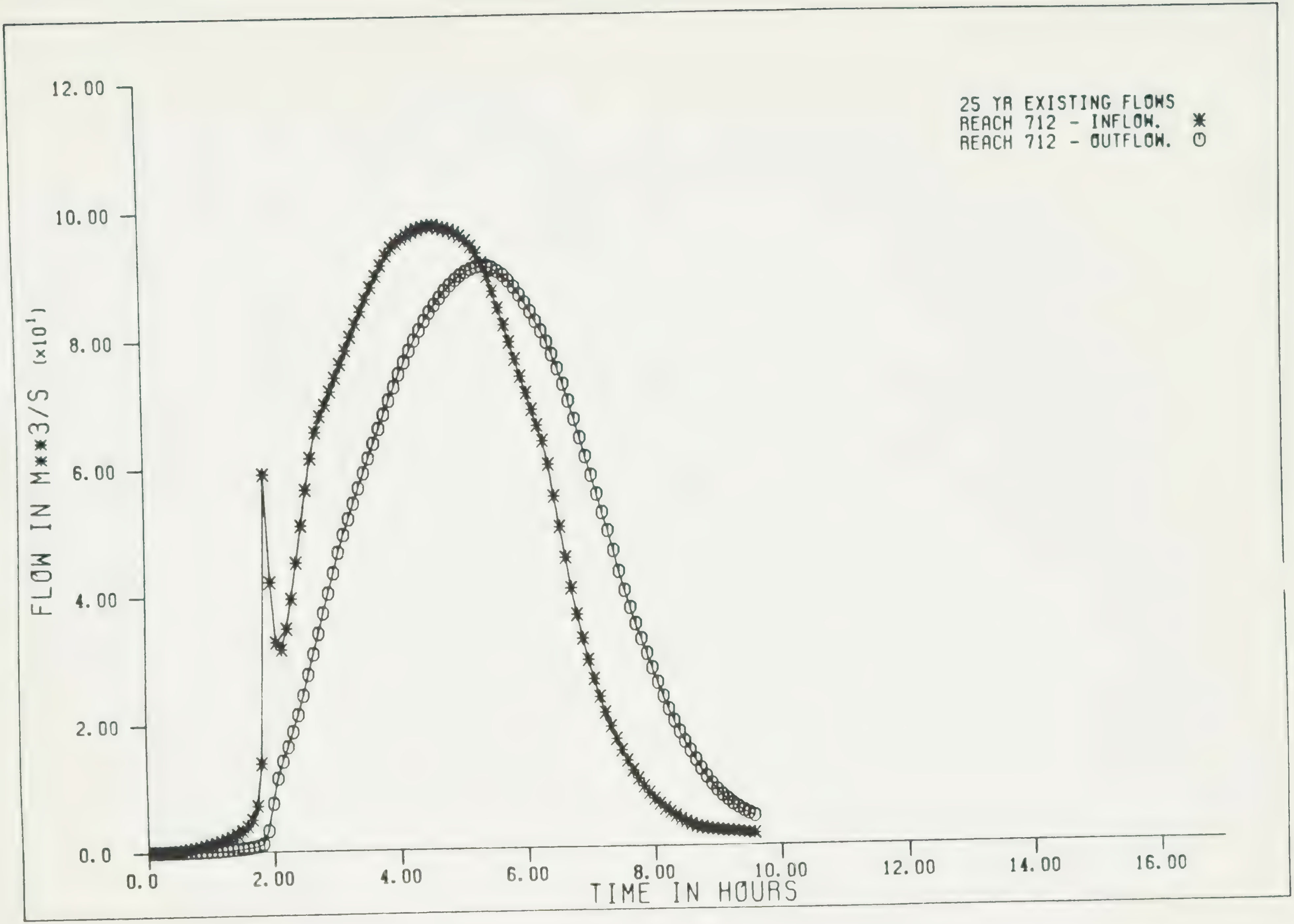


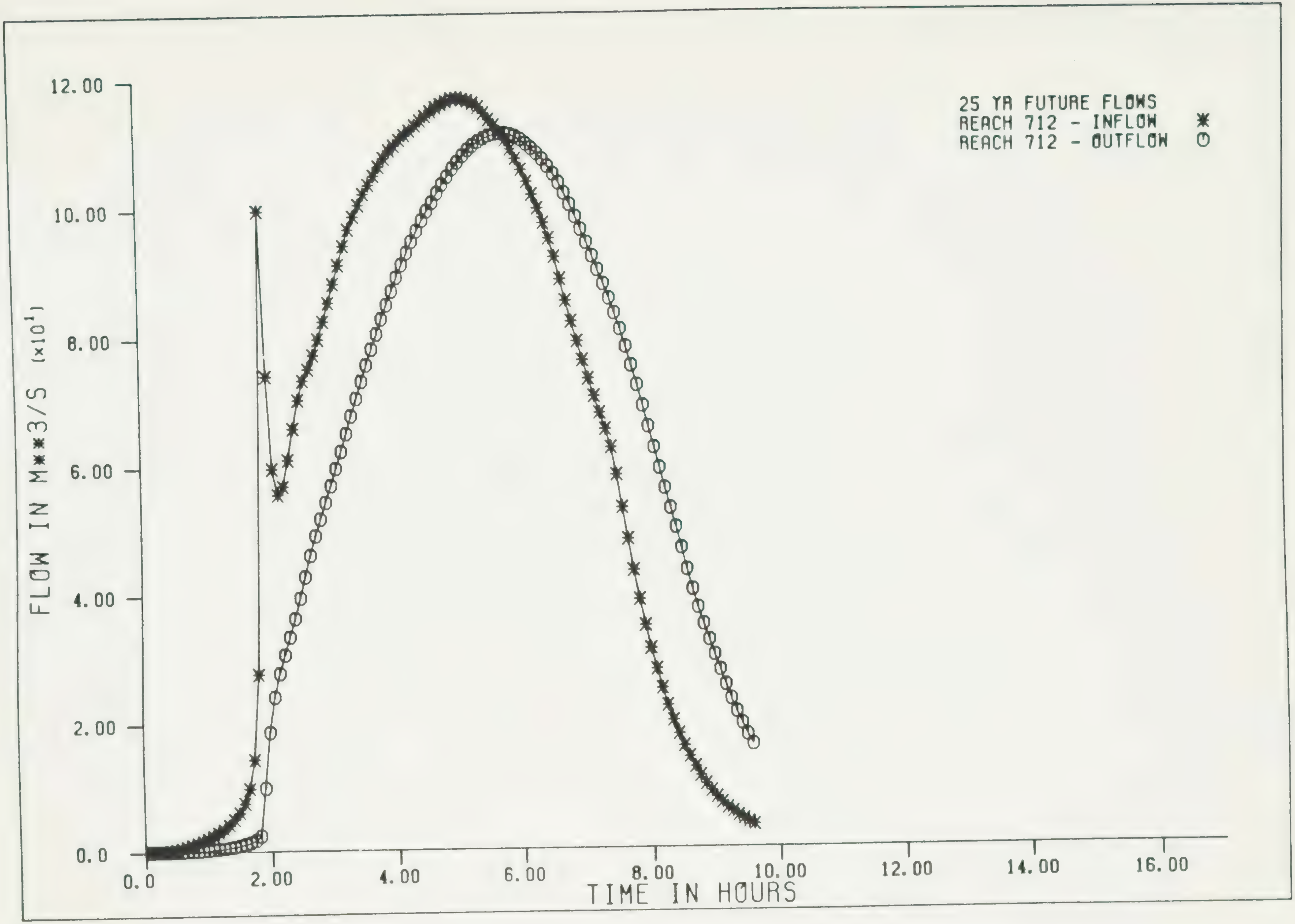
5 YR EXISTING FLOWS
REACH 712 - INFLOW. *
REACH 712 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


5 YEAR FUTURE FLOWS
REACH 712 - INFLOW. *
REACH 712 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
RS

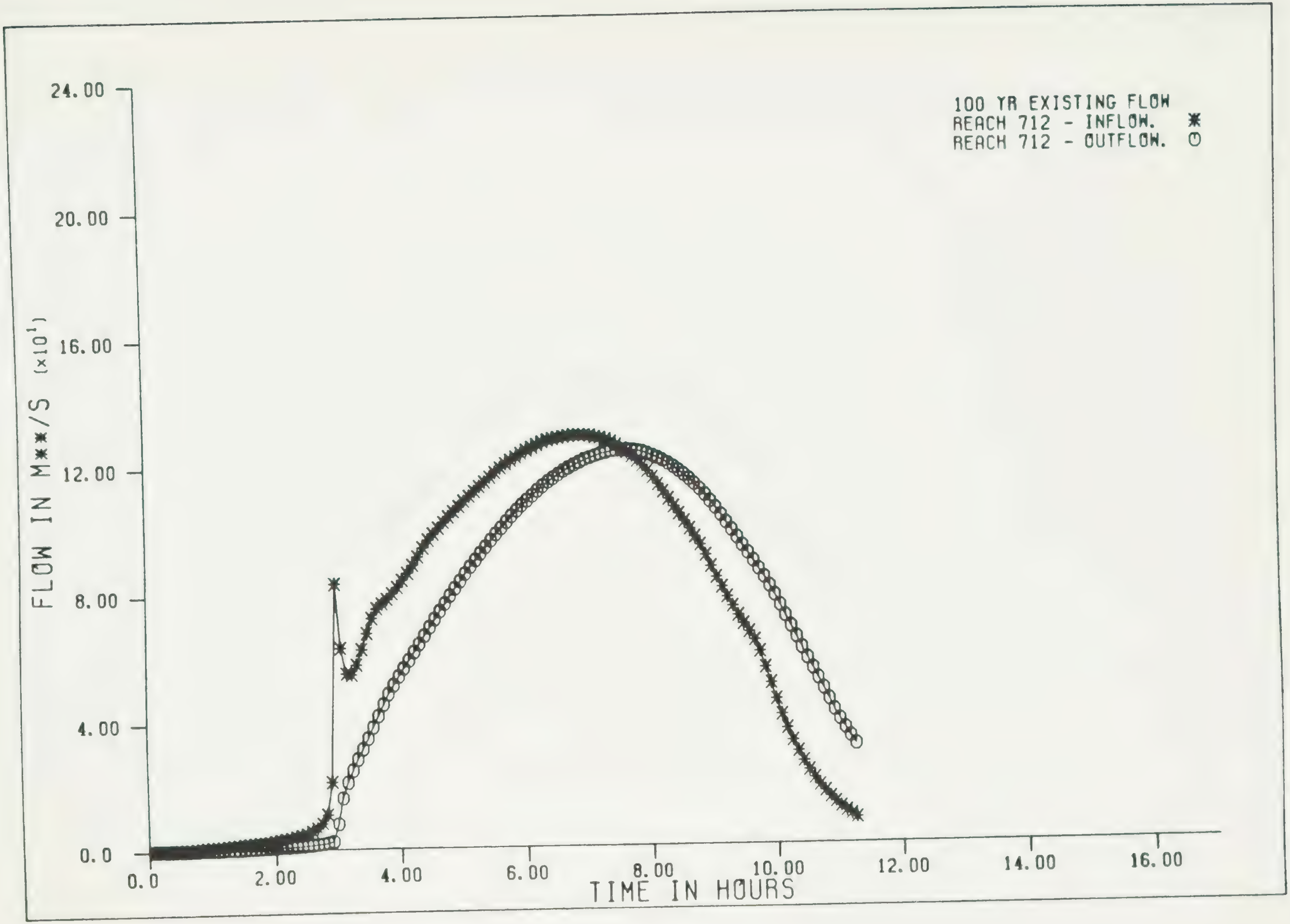

10 YR EXISTING FLOWS
REACH 712 - INFLOW. ✱
REACH 712 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

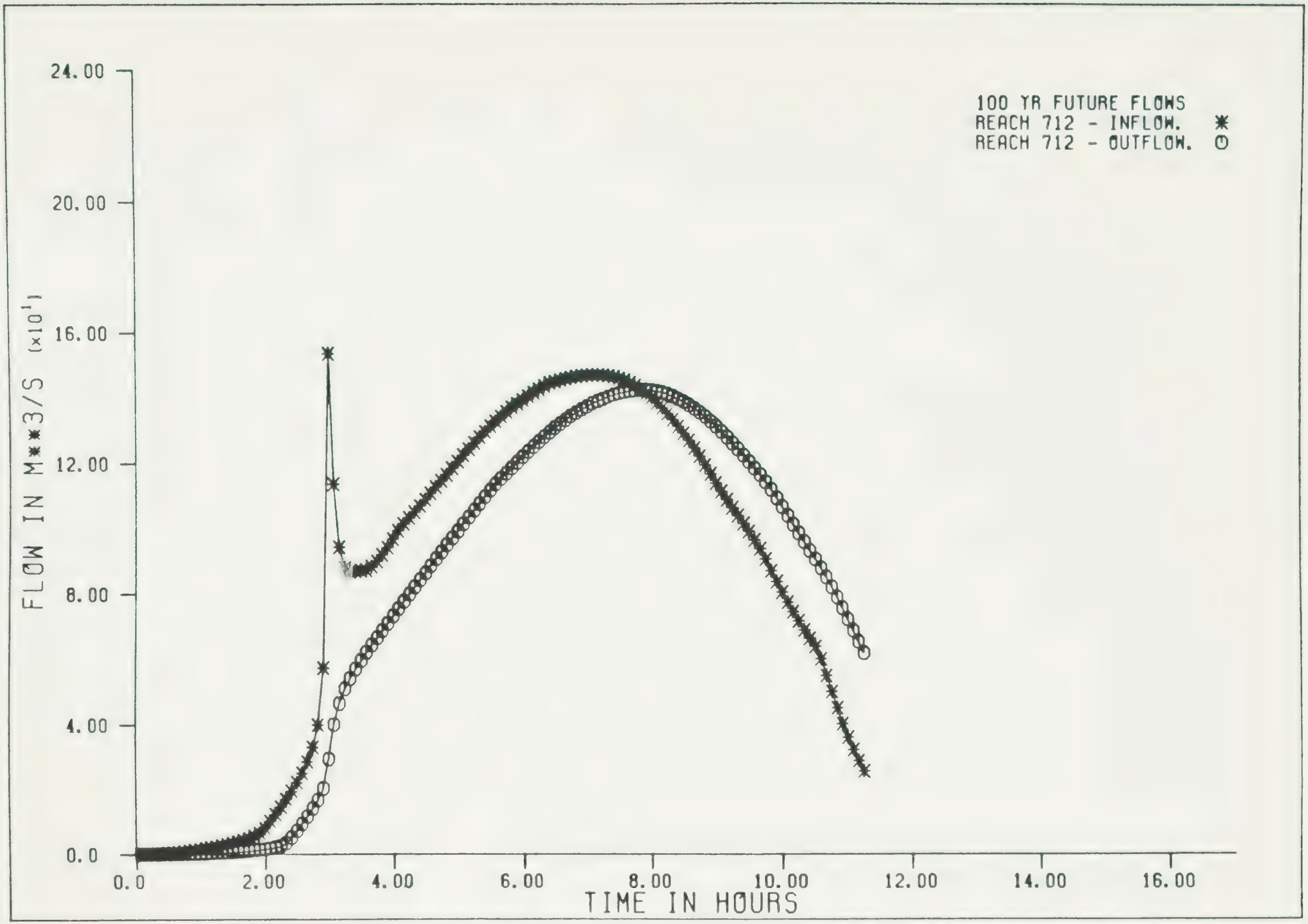

10 YR FUTURE FLOWS.
REACH 712 - INFLOW. *
REACH 712 - OUTFLOW. ⊖
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

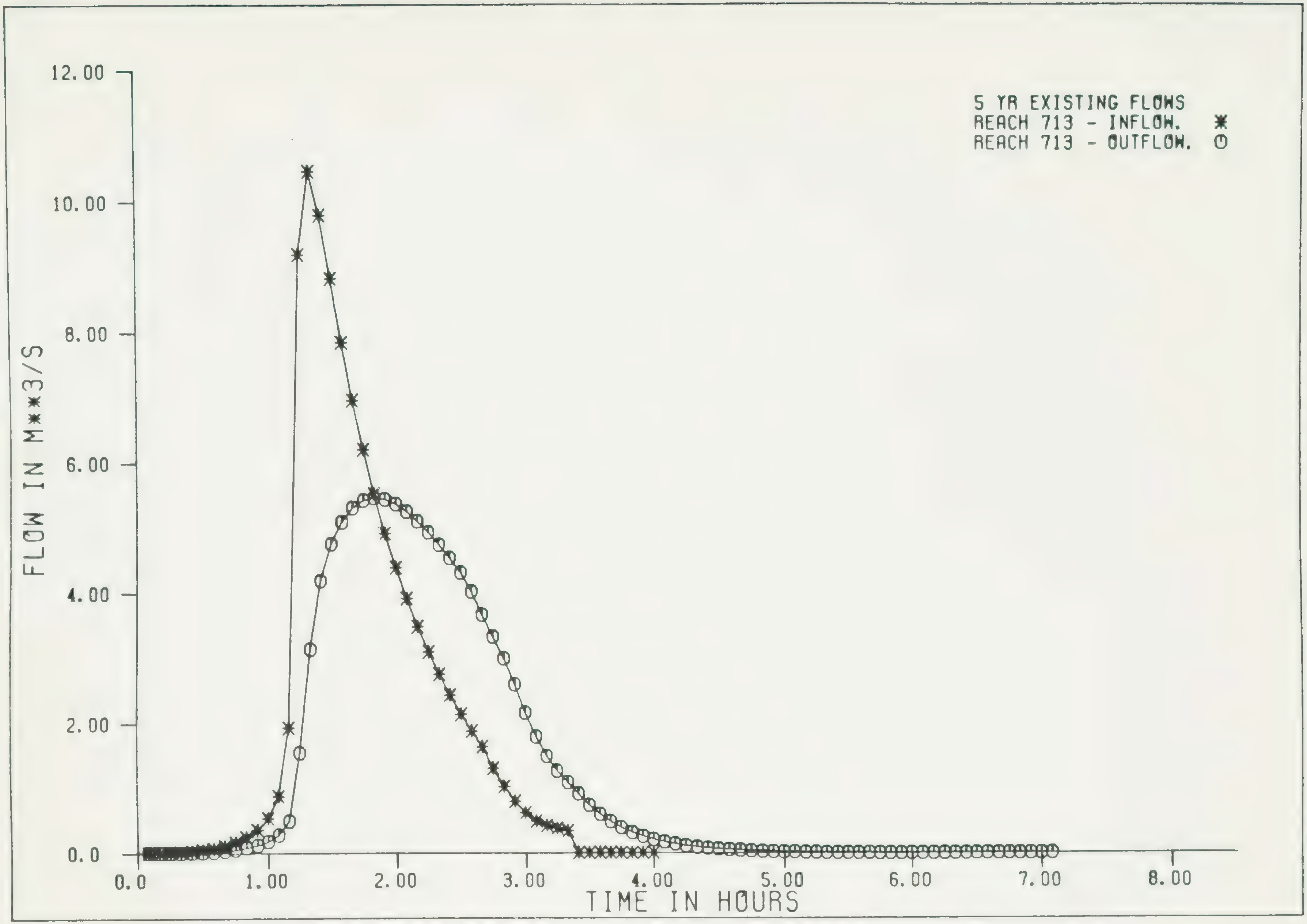

25 YR EXISTING FLOWS
REACH 712 - INFLOW. *
REACH 712 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

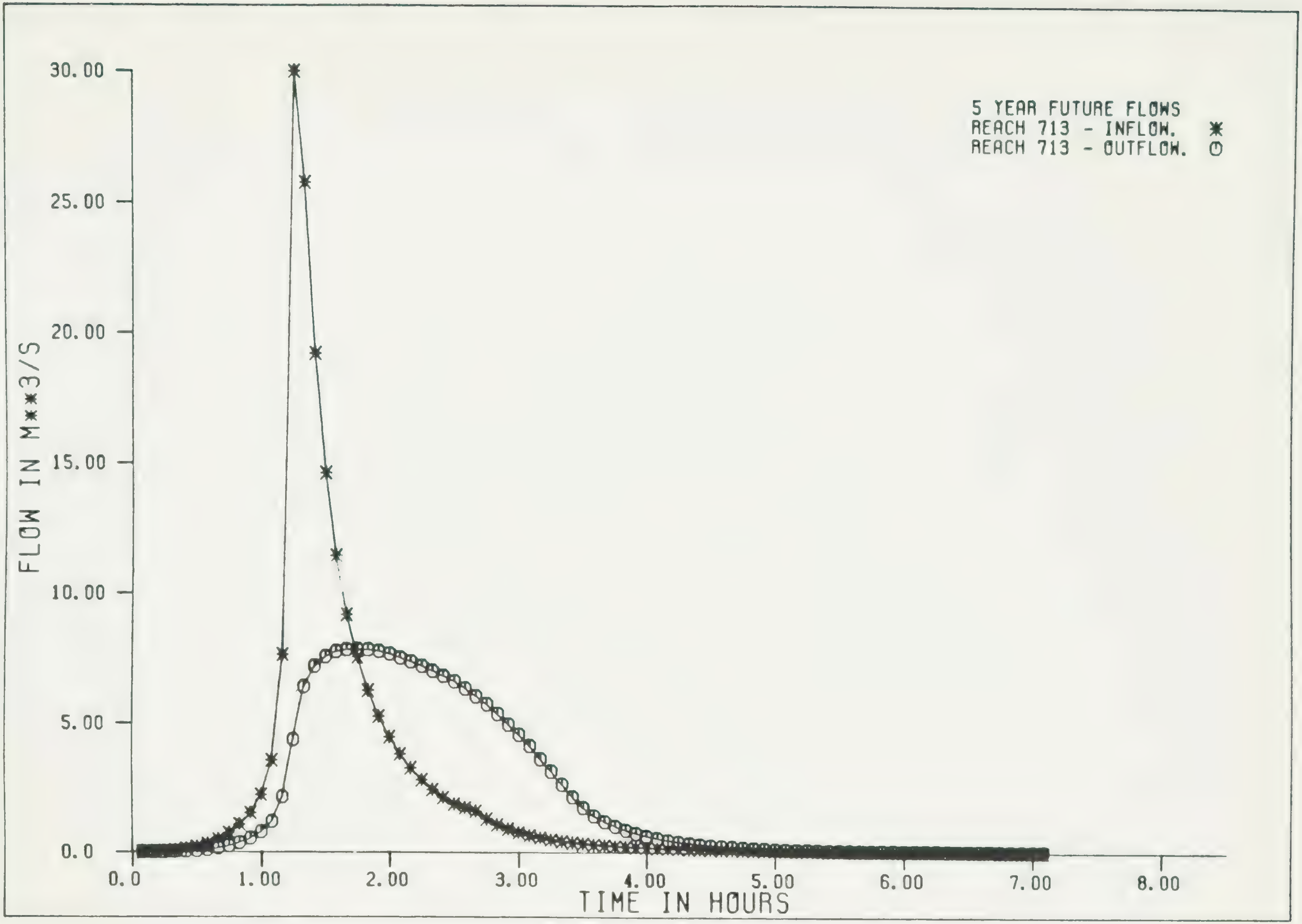


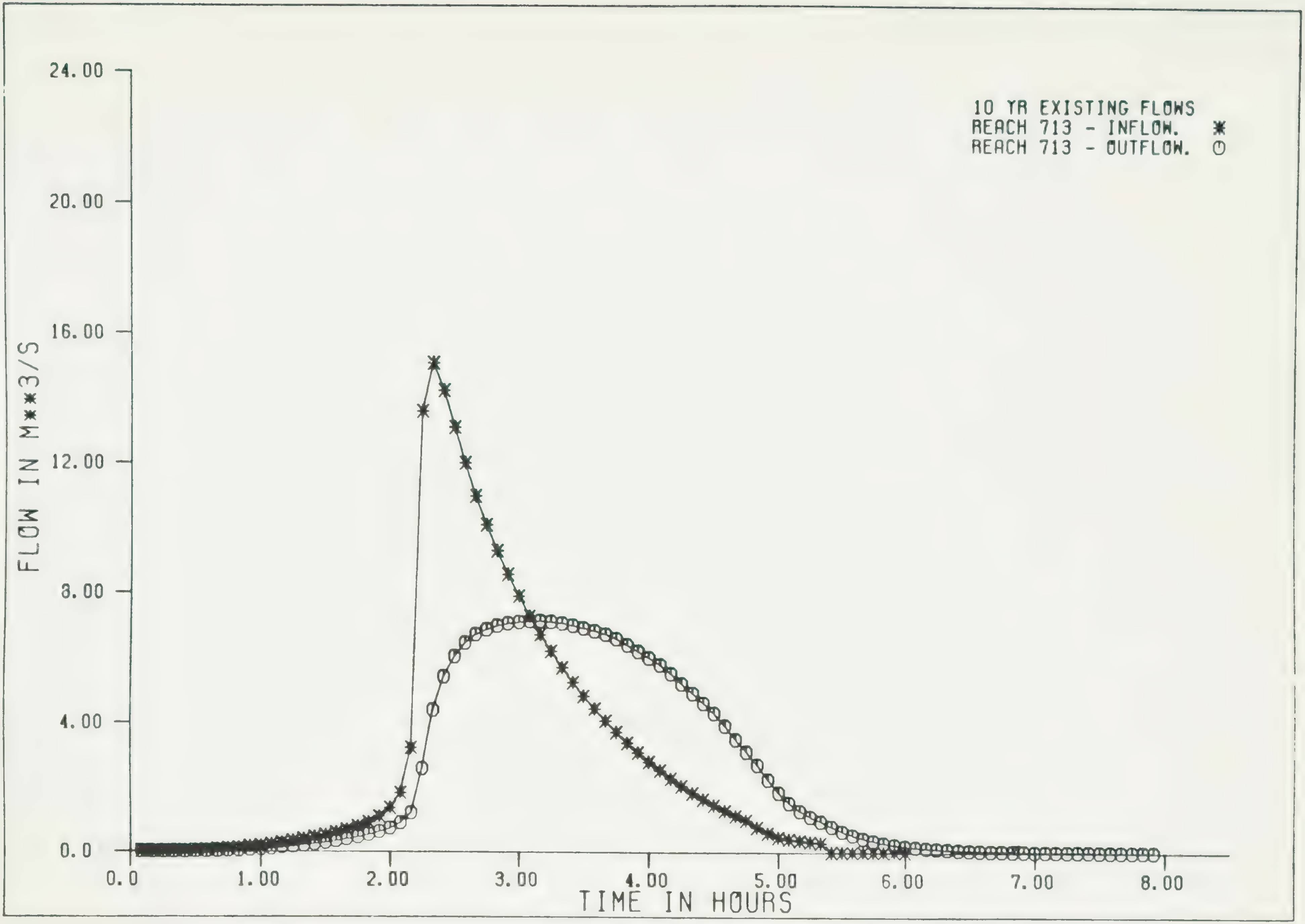
25 YR FUTURE FLOWS
REACH 712 - INFLOW *
REACH 712 - OUTFLOW O
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

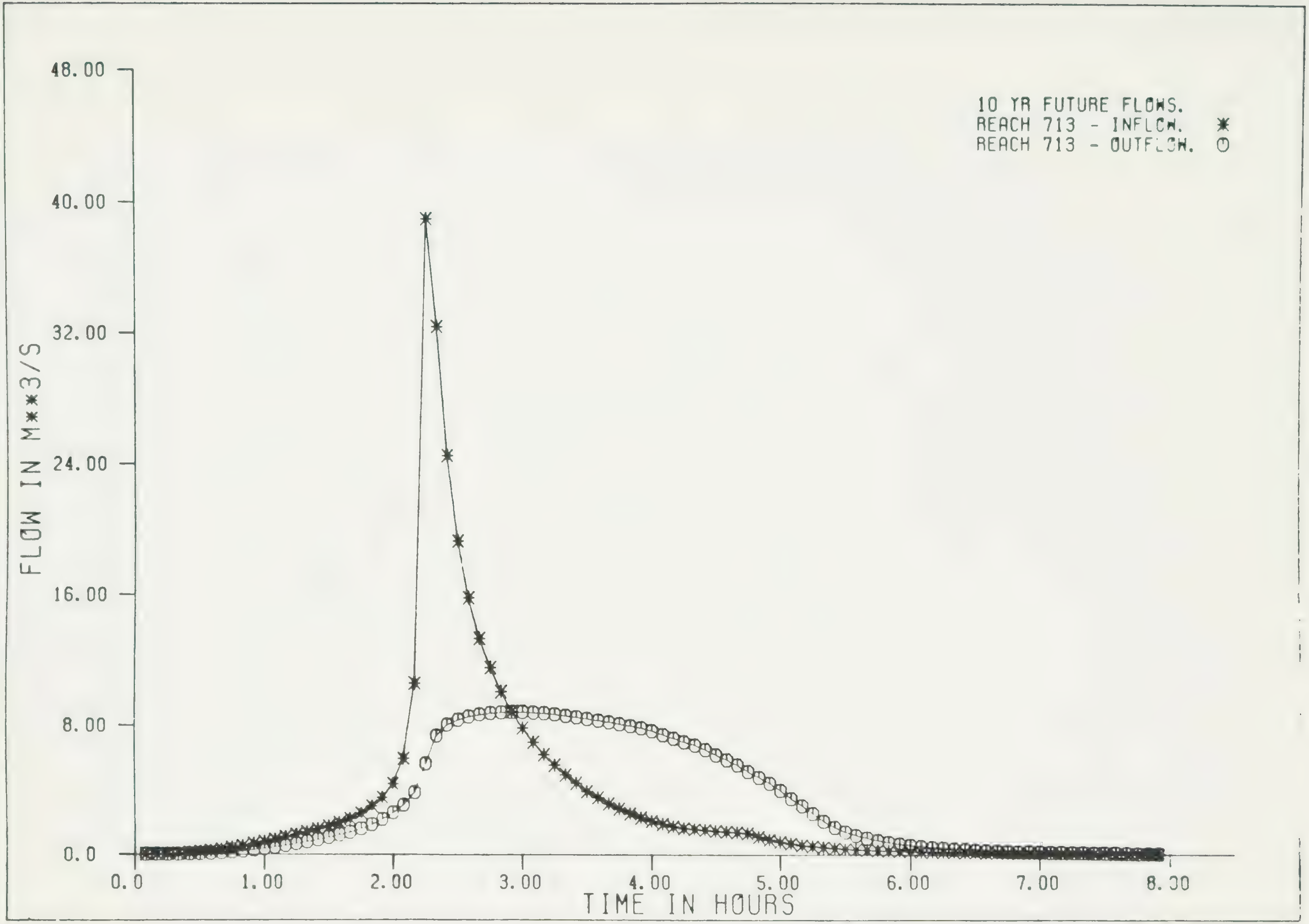

100 YR EXISTING FLOW
REACH 712 - INFLOW. *
REACH 712 - OUTFLOW. O
FLOW IN M**/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

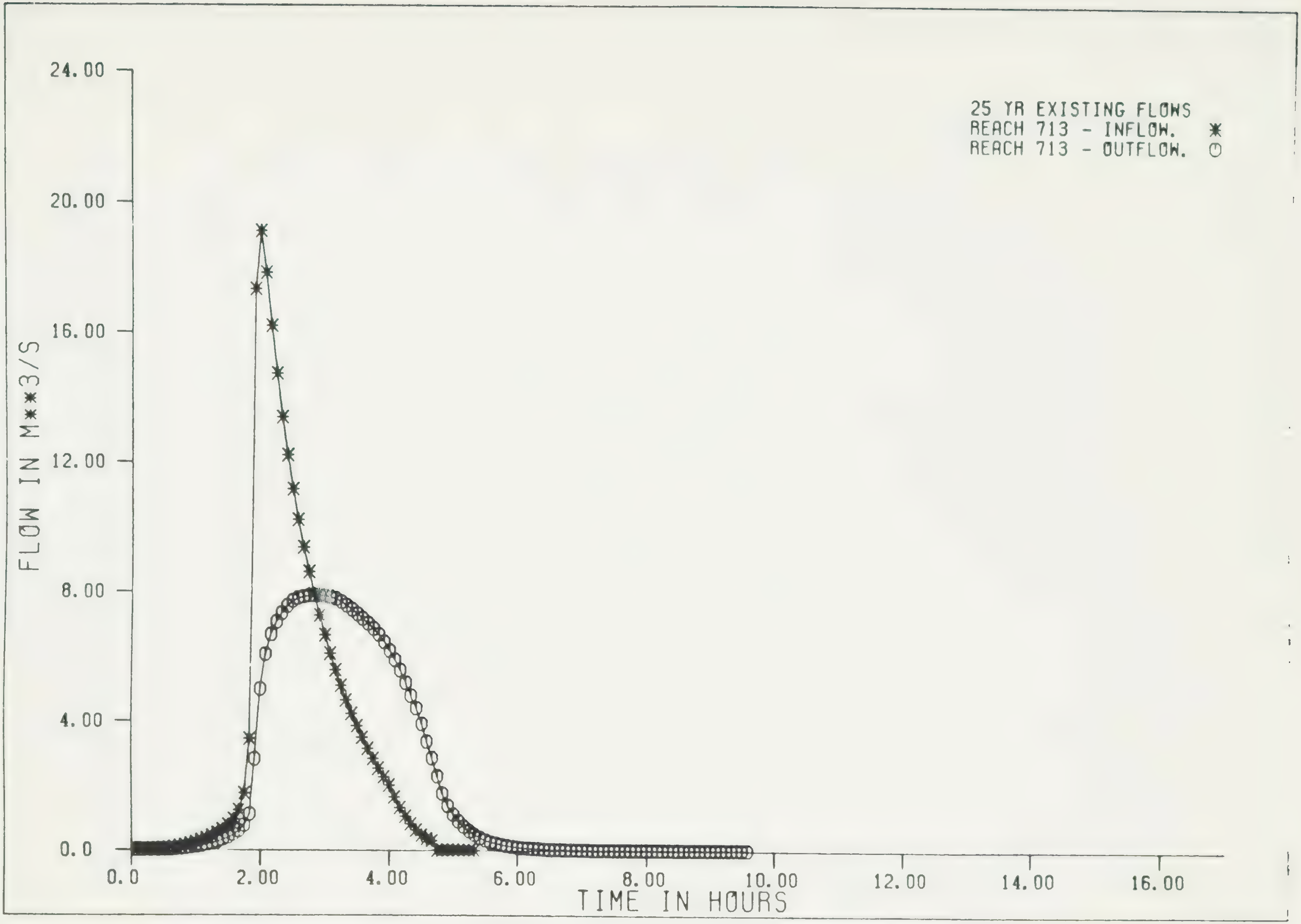

100 YR FUTURE FLOWS
REACH 712 - INFLOW. *
REACH 712 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

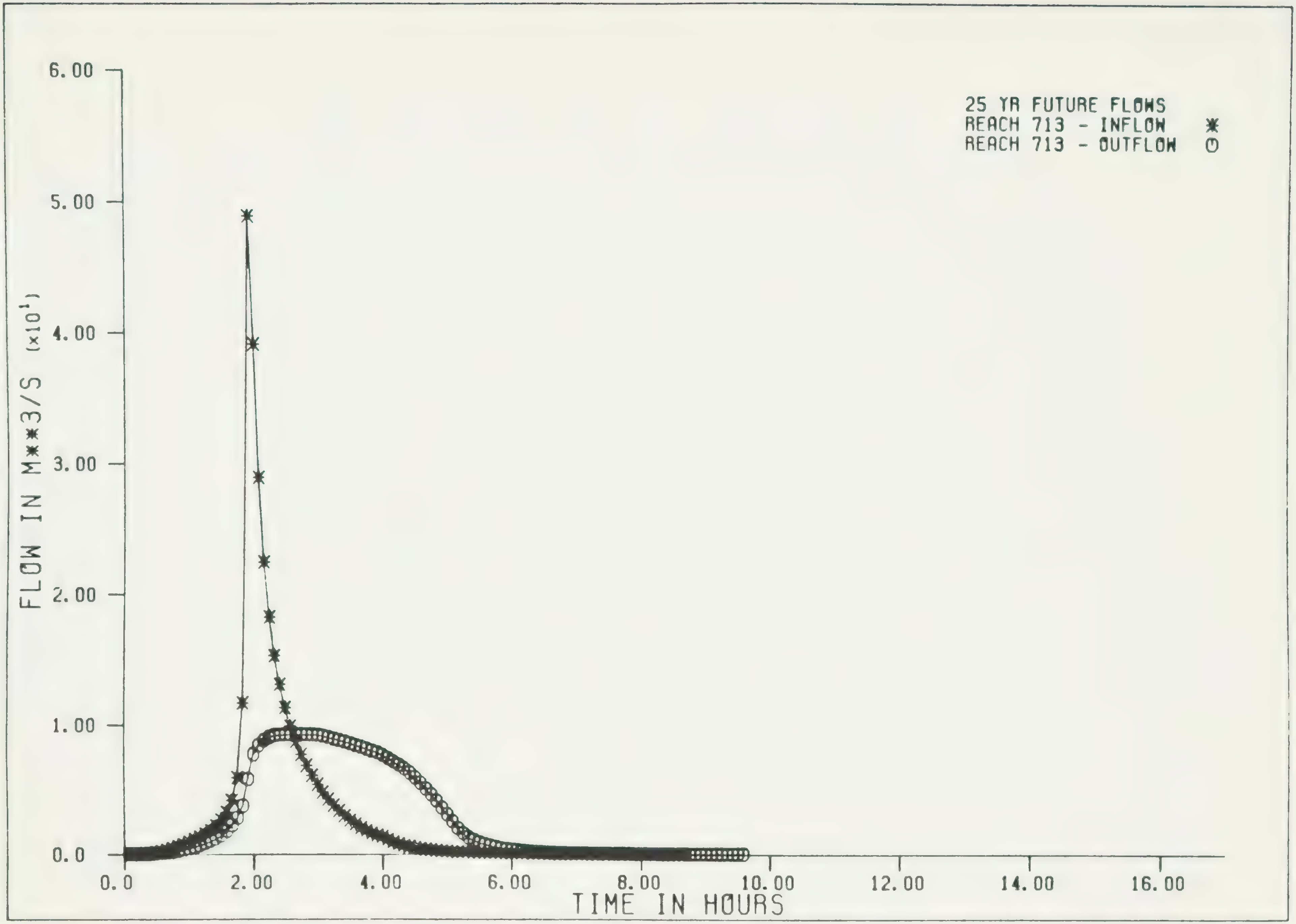

5 YR EXISTING FLOWS
REACH 713 - INFLOW. *
REACH 713 - OUTFLOW. O
FLOW IN M**3/S
TIME IN HOURS
12.00
10.00
8.00
6.00
4.00
2.00
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00

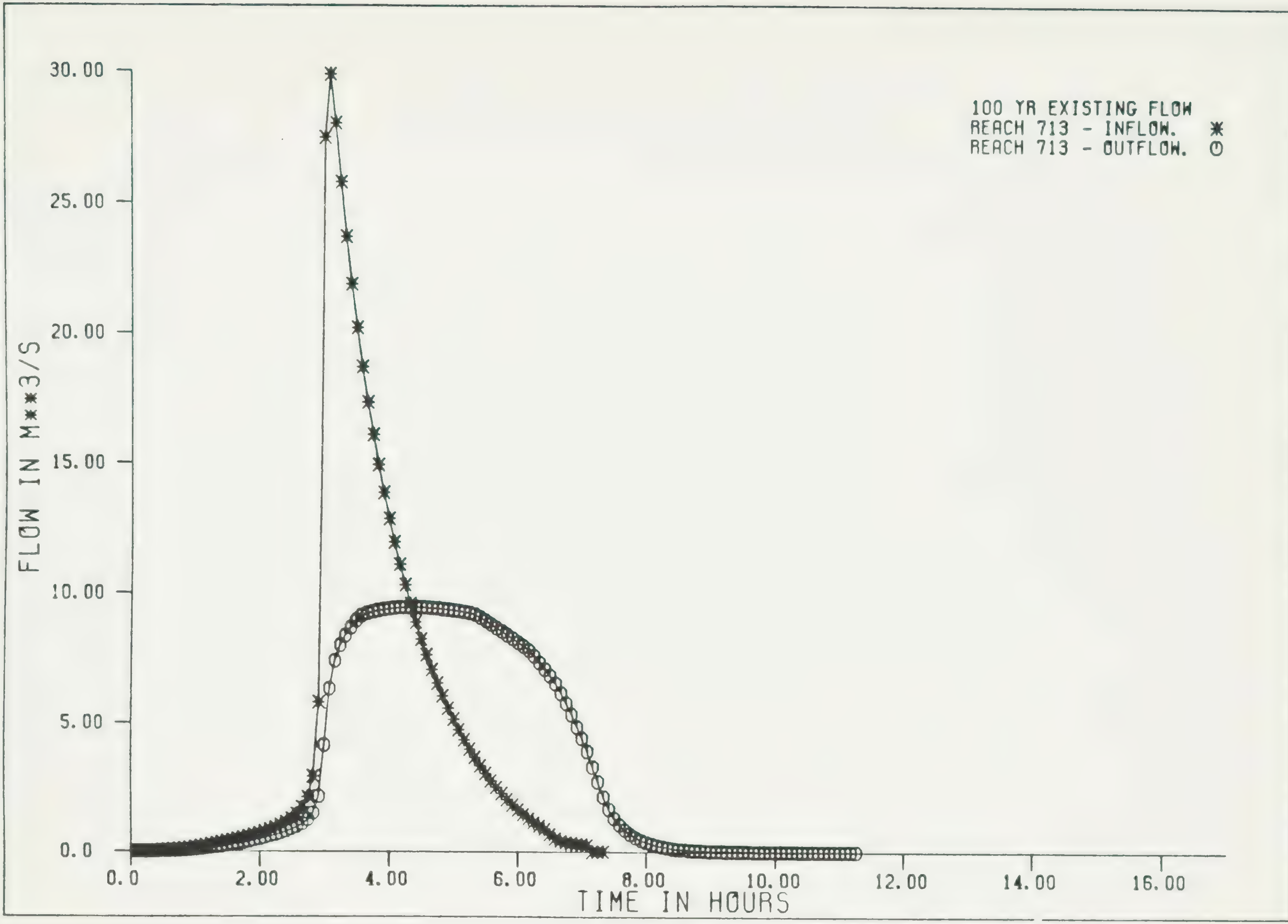

5 YEAR FUTURE FLOWS
REACH 713 - INFLOW. ✱
REACH 713 - OUTFLOW. O
FLOW IN M**3/S
30.00
25.00
20.00
15.00
10.00
5.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

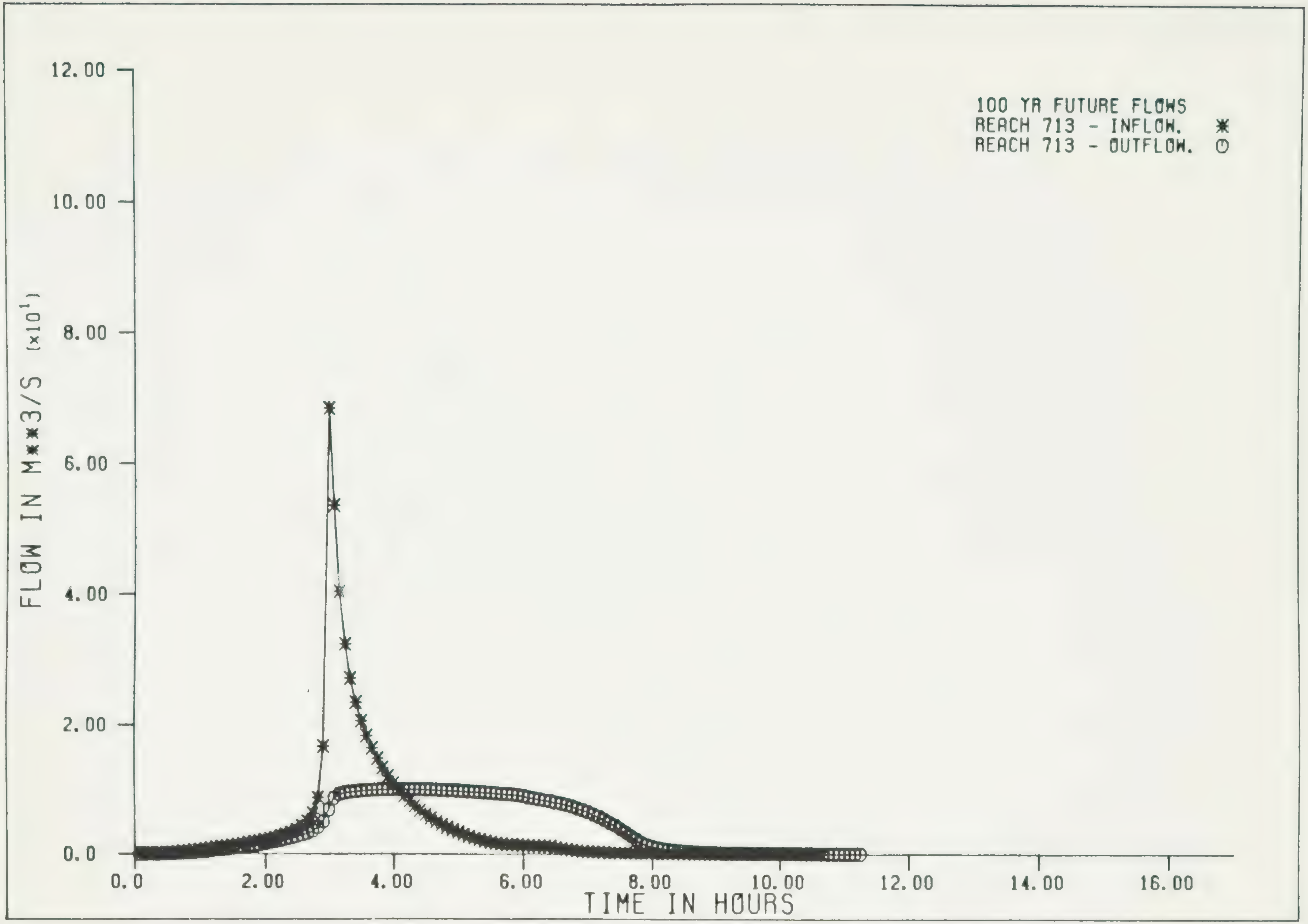

10 YR EXISTING FLOWS
REACH 713 - INFLOW. *
REACH 713 - OUTFLOW. O
FLOW IN M**3/S
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


10 YR FUTURE FLOWS.
REACH 713 - INFLOW. *
REACH 713 - OUTFLOW. O
FLOW IN M**3/S
48.00
40.00
32.00
24.00
16.00
8.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

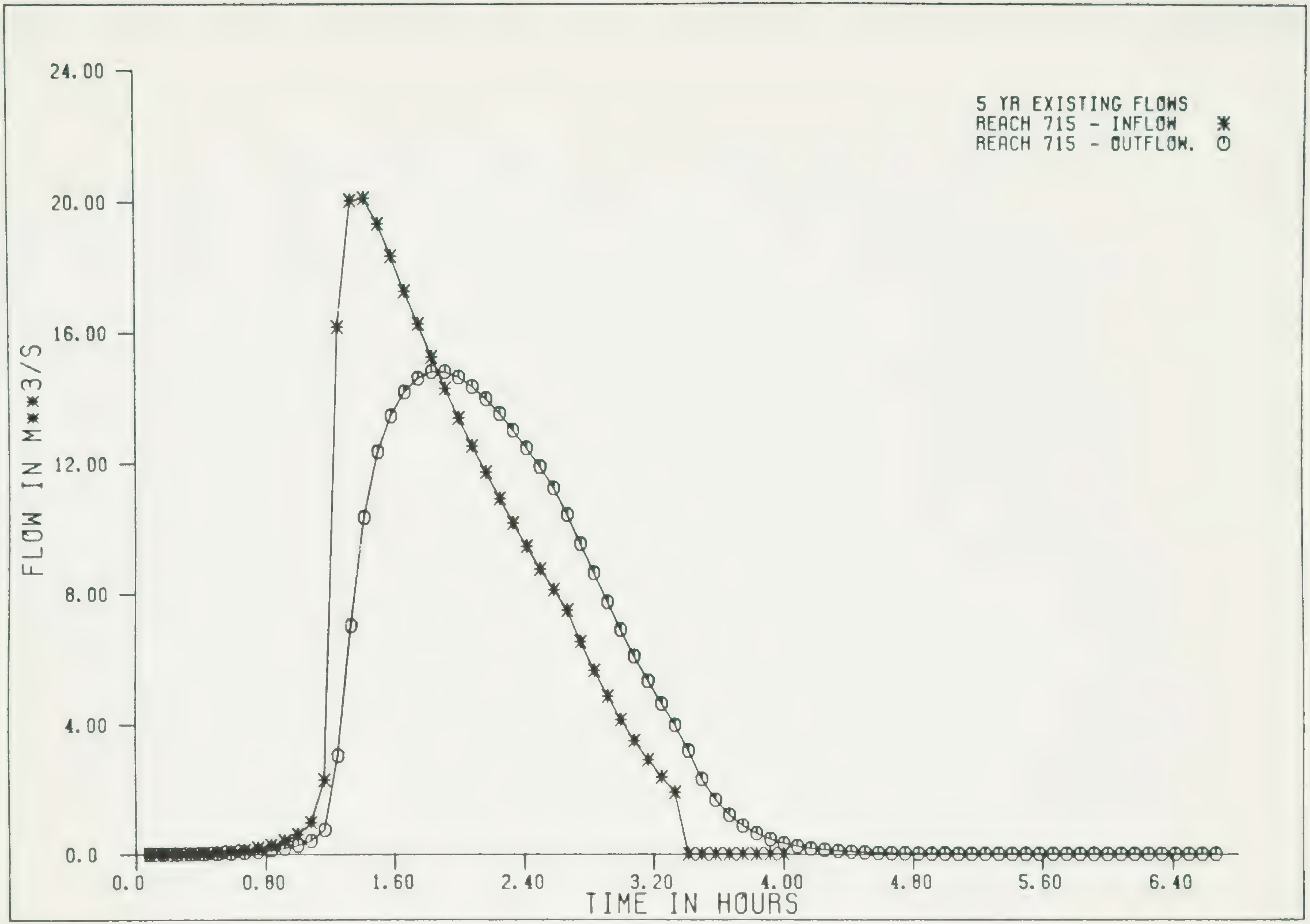

25 YR EXISTING FLOWS
REACH 713 - INFLOW. *
REACH 713 - OUTFLOW. O
FLOW IN M**3/S
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

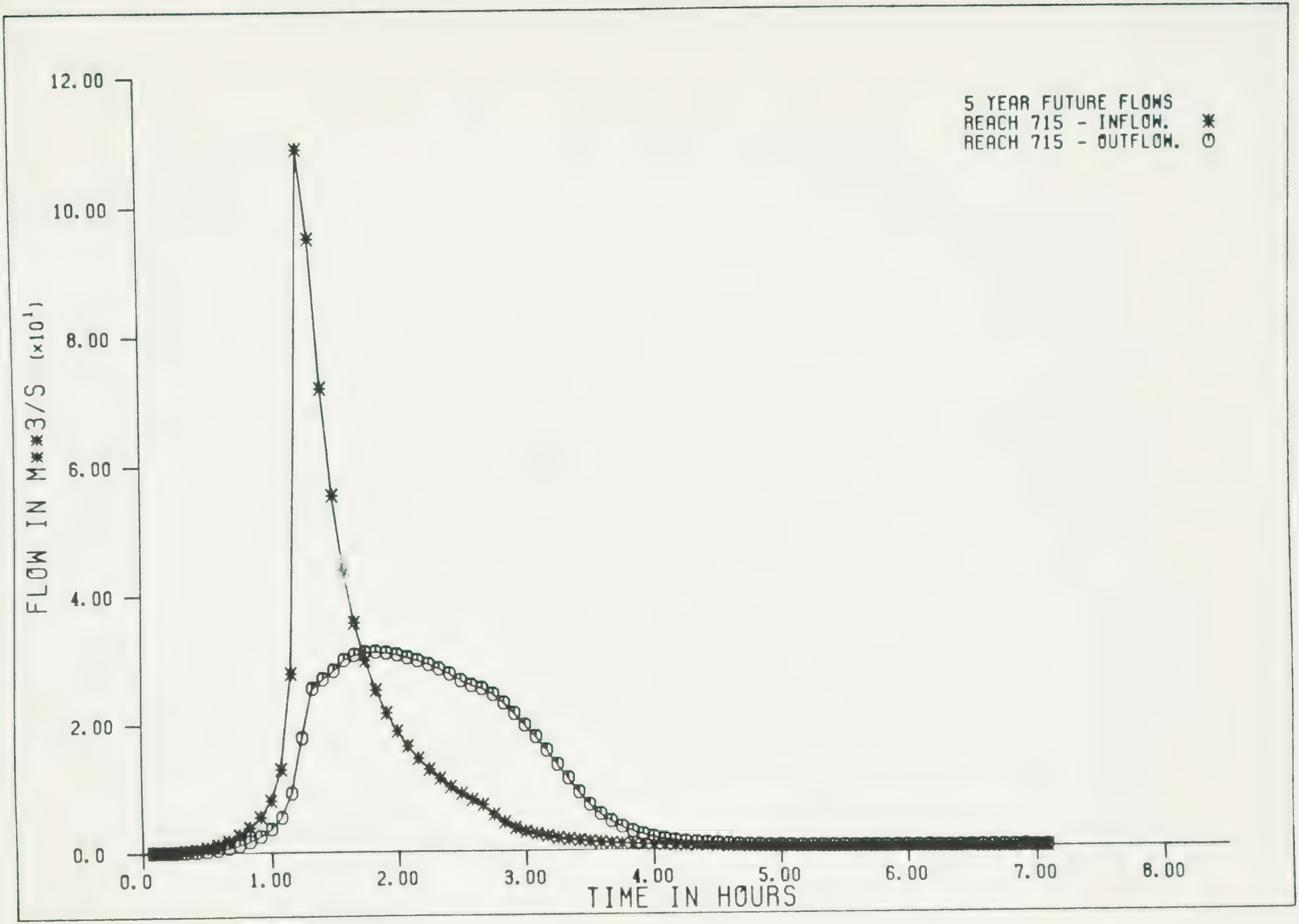

25 YR FUTURE FLOWS
REACH 713 - INFLOW
REACH 713 - OUTFLOW
6.00
5.00
4.00
3.00
2.00
1.00
0.0
FLOW IN M**3/S (x10¹)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

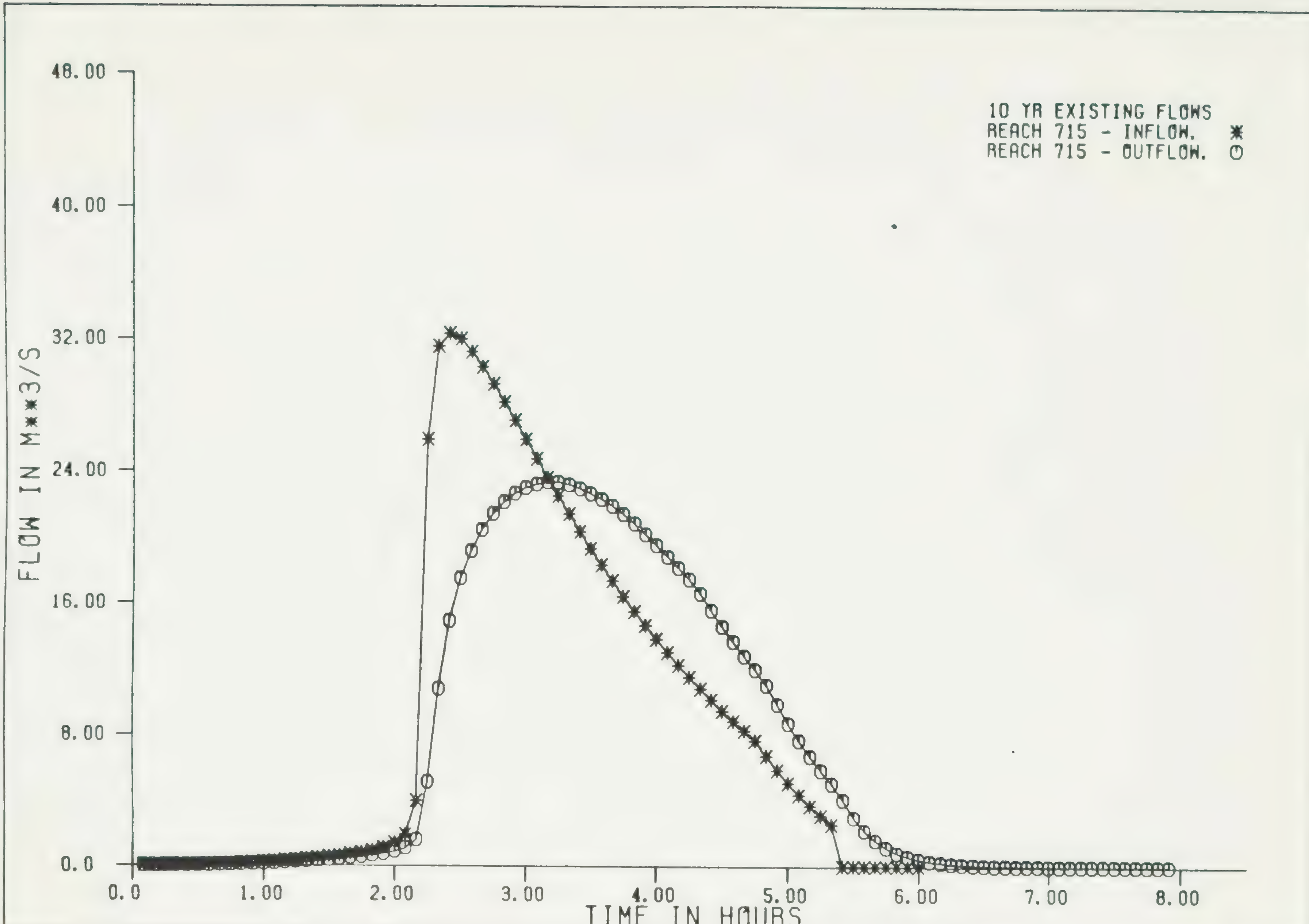

100 YR EXISTING FLOW
REACH 713 - INFLOW. *
REACH 713 - OUTFLOW. O
FLOW IN M**3/S
30.00
25.00
20.00
15.00
10.00
5.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS



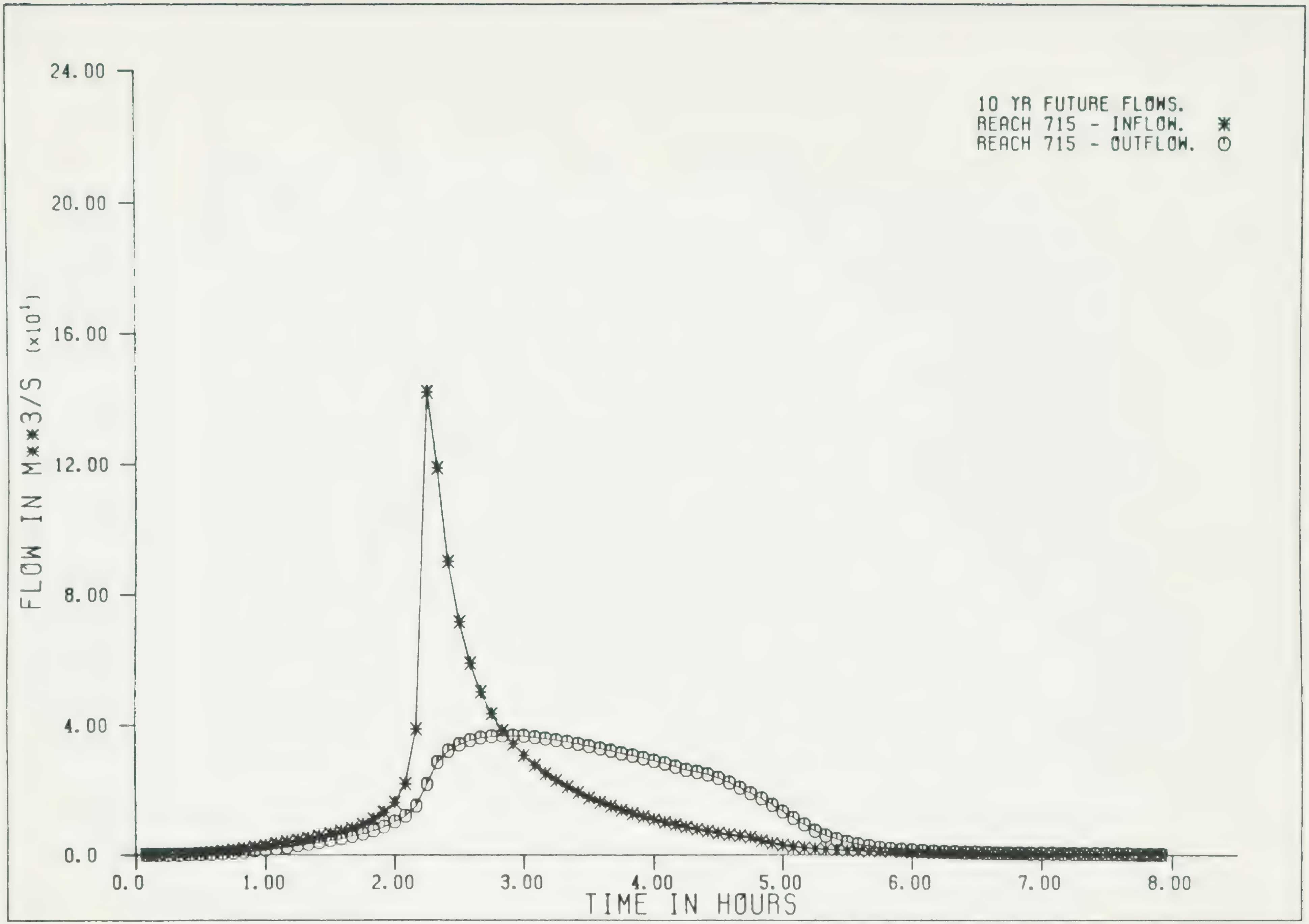
100 YR FUTURE FLOWS
REACH 713 - INFLOW.
REACH 713 - OUTFLOW.
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS

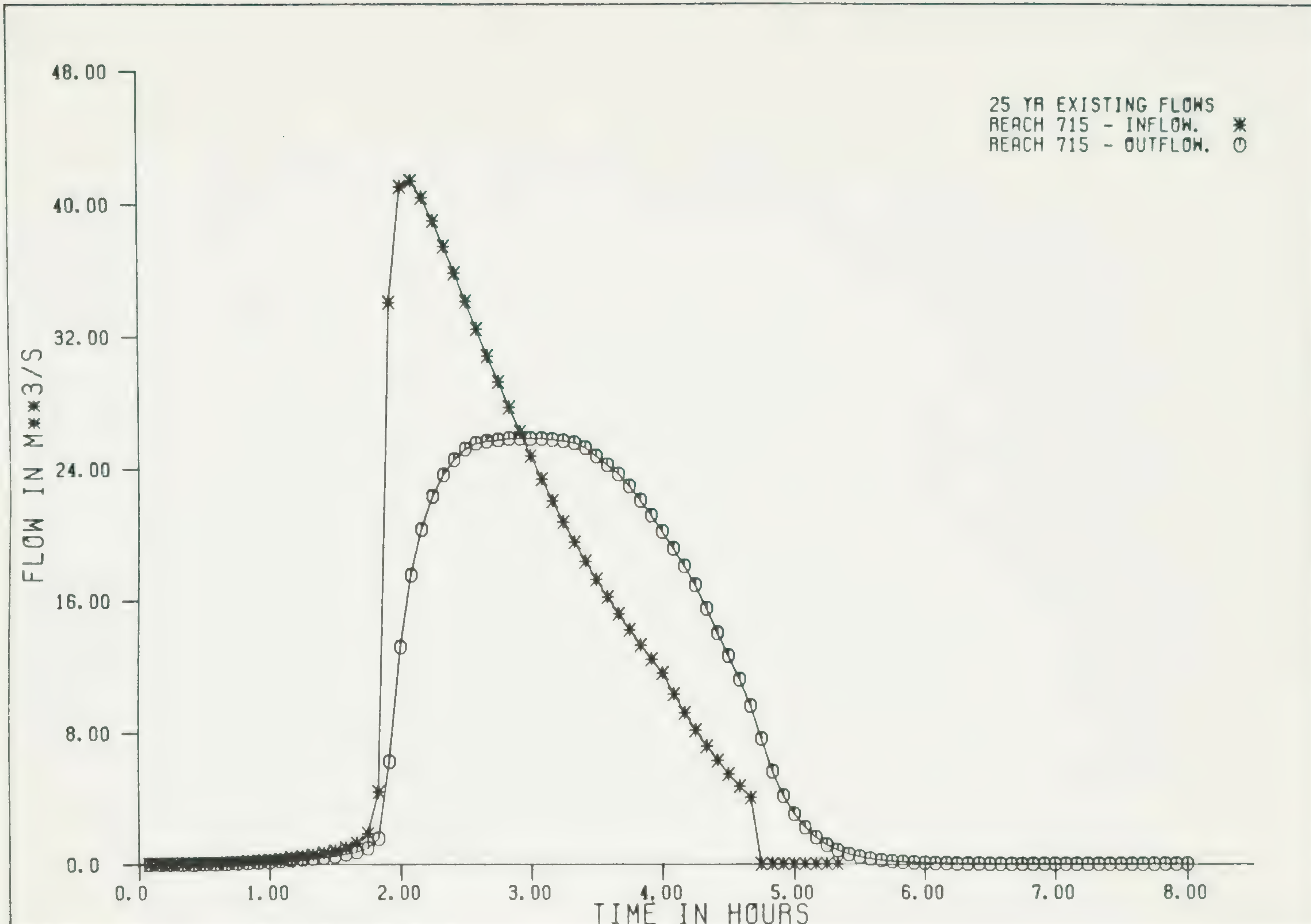

5 YR EXISTING FLOWS
REACH 715 - INFLOW *
REACH 715 - OUTFLOW. O
FLOW IN M**3/S
TIME IN HOURS
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
0.80
1.60
2.40
3.20
4.00
4.80
5.60
6.40


5 YEAR FUTURE FLOWS
REACH 715 - INFLOW. ✱
REACH 715 - OUTFLOW. ⊖
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

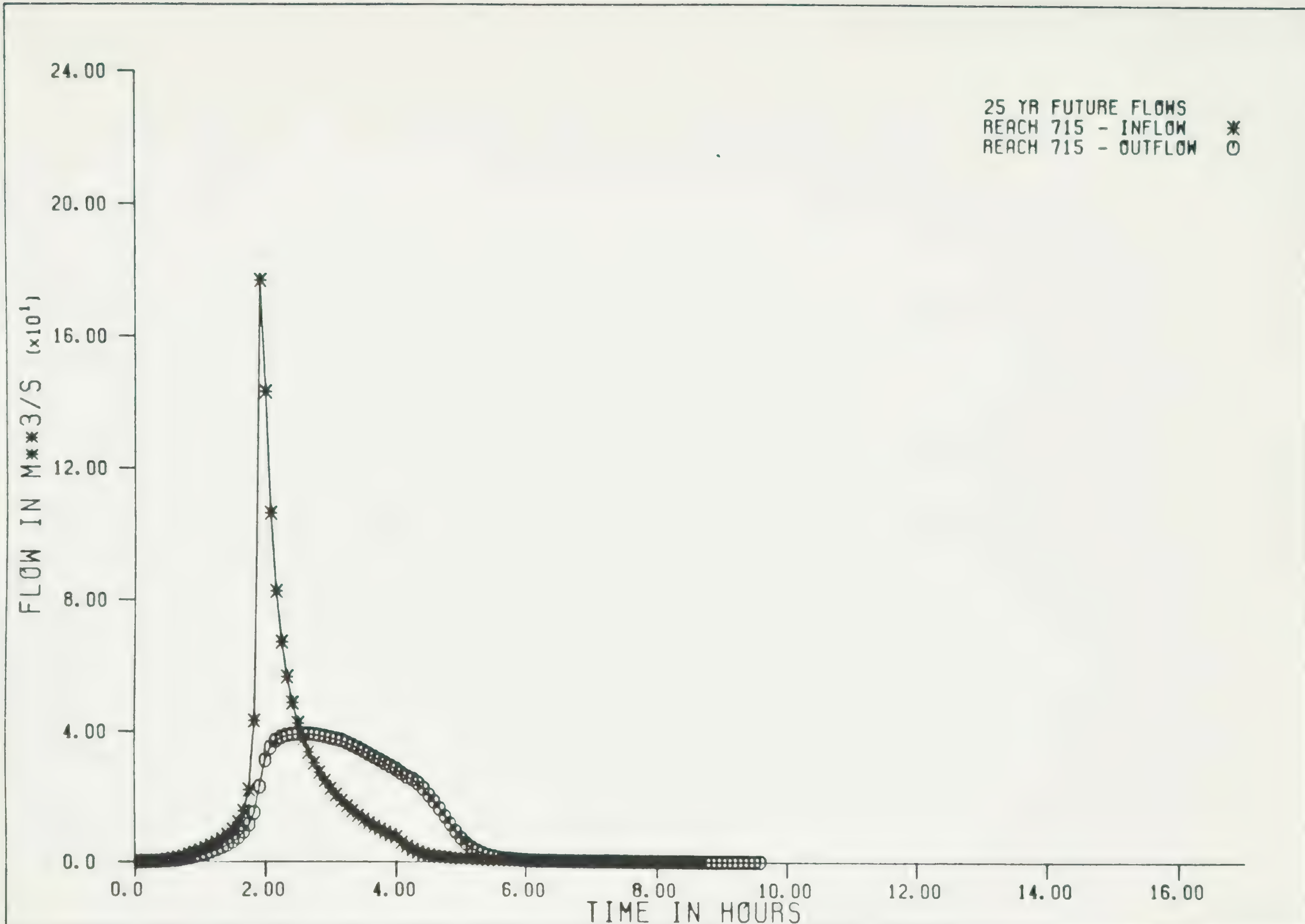


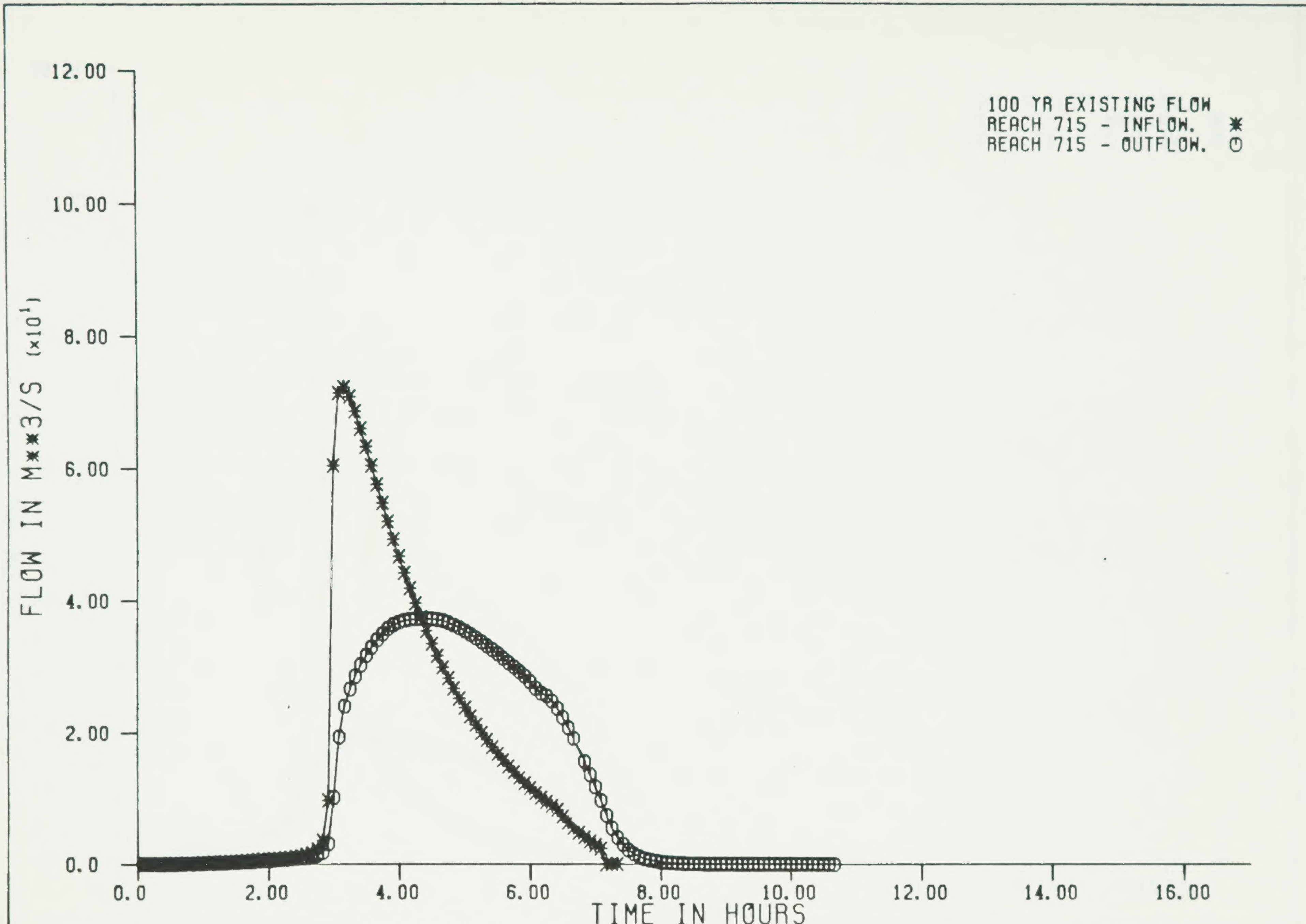
10 YR EXISTING FLOWS
REACH 715 - INFLOW. *
REACH 715 - OUTFLOW. O
48.00
40.00
32.00
24.00
16.00
8.00
0.0
FLOW IN M**3/S
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS

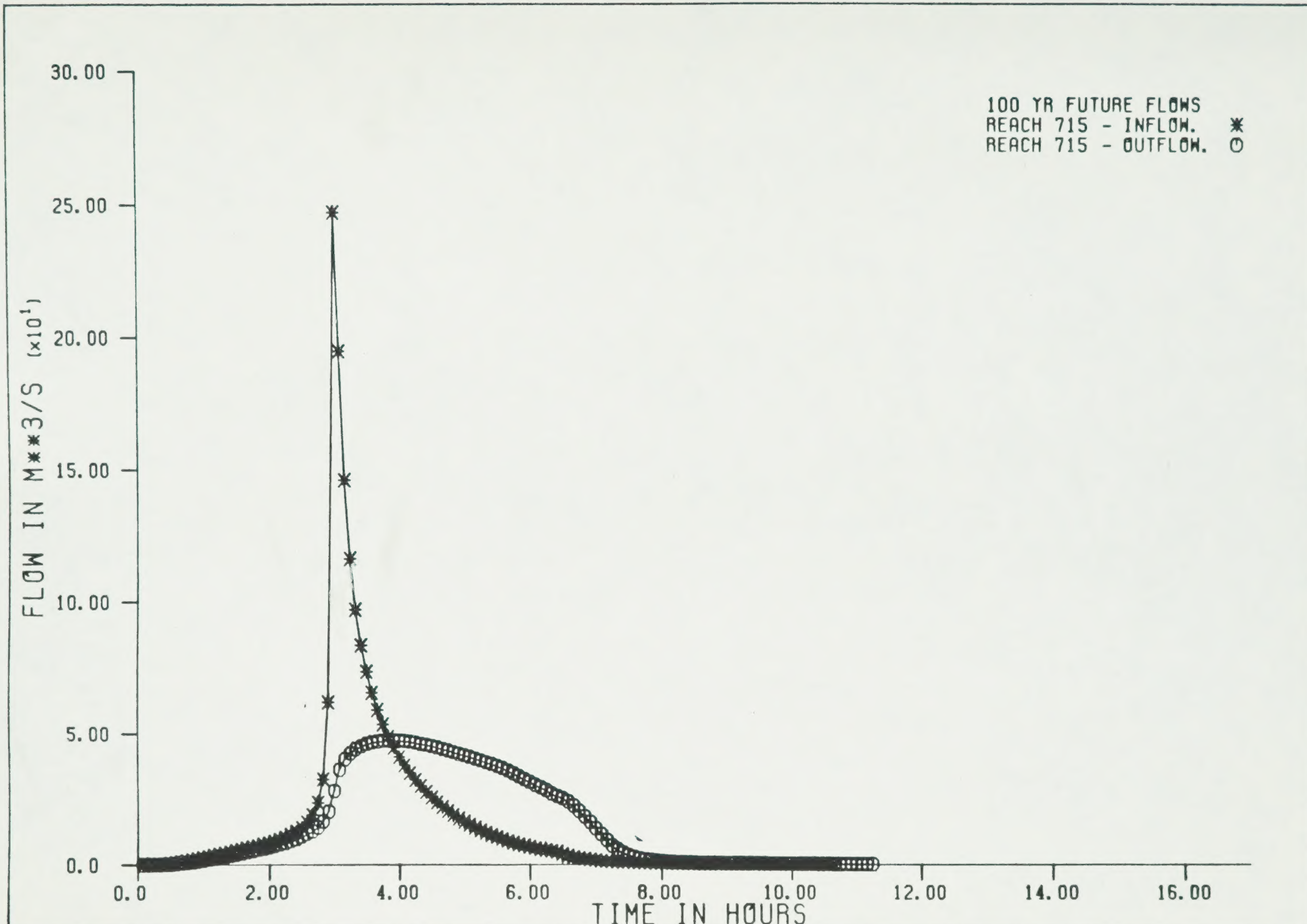

10 YR FUTURE FLOWS.
REACH 715 - INFLOW. *
REACH 715 - OUTFLOW. O
FLOW IN M**3/S (x10¹)
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS



25 YR EXISTING FLOWS
REACH 715 - INFLOW. *
REACH 715 - OUTFLOW. O
48.00
40.00
32.00
24.00
16.00
8.00
0.0
FLOW IN M**3/S
0.0
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
TIME IN HOURS


25 YR FUTURE FLOWS
REACH 715 - INFLOW *
REACH 715 - OUTFLOW O
FLOW IN M**3/S (x10[1])
24.00
20.00
16.00
12.00
8.00
4.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS


100 YR EXISTING FLOW
REACH 715 - INFLOW. ✱
REACH 715 - OUTFLOW. ⊙
FLOW IN M**3/S (x10¹)
12.00
10.00
8.00
6.00
4.00
2.00
0.0
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS


100 YR FUTURE FLOWS
REACH 715 - INFLOW. *
REACH 715 - OUTFLOW. O
30.00
25.00
20.00
15.00
10.00
5.00
0.0
FLOW IN M**3/S (x10^1)
0.0
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
TIME IN HOURS